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EDITOR'S OUTLOOK

The Frontispiece

THE frontispiece of this issue of the JOURNAL OF CHEMICAL EDUCATION presents a cross-section of life at the court of Emperor Rudolph II, patron of the arts and science, whose intellectual interests, less than scholarly but more than trivial, made him the cautious but fascinated victim of a diverting procession of misguided scholars and scheming rascals tempted by alchemy from the straight and narrow path of legitimate science. The Bohemian painter, Vacslav von Brozik (1852–1901), here depicts a scene in a dark laboratory, presumably in Gold Alley, a little street of Prague, which attempted to live up to its name by harboring within its narrow confines seekers of the precious metal, students of the secret of transmutation, the earnest as well as the nonchalant. It was in this street that two of Rudolph's most colorful pensionaries, Englishmen both, the mathematician, alchemist, and astrologer, John Dee, and his clever but unscrupulous assistant, Edward Kelley, took up their residence when they came to Prague in 1583. Dee, a man of considerable learning fallen on evil days, astounded and edified the emperor by his scientific and philosophical disquisitions and thus managed to retain Rudolph's favor and liberality for himself and his colleague for a number of years. After Dee's return to England in 1589 at the invitation of Queen Elizabeth, an equally confident but less bountiful patron than Rudolph, Kelley remained in Prague. Known as the Golden Knight, he pushed a very successful career as court alchemist to its own undoing by devising for Rudolph's admiration various transmutation tricks, such as that shown in Brozik's picture, in which a practitioner is seen extending to the stolid but interested emperor and his more openly curious courtiers a broken crucible containing an ingot of gold. Contrasted with the elegance of the imperial and court costumes are instruments of the alchemist's trade, the furnace and hood, the alembic, and apparatus and manuscripts scattered with impressive unconcern throughout the laboratory.

This picture was painted in Paris in 1881 and exhibited at the Salon in the following year. It hangs in the Stuart Gallery of the New York Public Library.

The JOURNAL OF CHEMICAL EDUCATION *is indebted for information regarding this picture to* MR. C. RESS, *of the Scientific Equipment Co., New York City,* DR. TENNEY L. DAVIS, *of the Massachusetts Institute of Technology, and* MR. H. M. LYDENBERG, *Assistant Director of the New York Public Library.*

THE final report of the A. C. S. Committee on Prize Essays brings to a formal conclusion one phase of the most ambitious and, we believe, the most effective project in popular chemical education ever undertaken.

1911
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Record of an Achievement

In order to appreciate fully what has been accomplished it is necessary to compare the conditions of the present day with those which existed at the time of the entrance of the United States into the World War.

On October 6, 1917, the Trading with the Enemy Act became a law of the United States. This Act empowered the President to seize all property, situated in the United States, that belonged to citizens of Germany and her allies, and created the office of Alien Property Custodian to administer such seized property. At the invitation of President Wilson, Mr. Francis P. Garvan undertook the task of locating enemy property (much of it skilfully concealed) and of directing its seizure.

The most significant disclosure made, incident to this task, was the revelation of the extent of our dependency upon Germany for dyes, drugs, and chemicals. Not only was the United States lacking in a fine chemical industry worthy of the name, but the road to the development of such an industry was blocked by thousands of German patents on file in our Patent Office. These patents were not being exploited in the United States but had served solely to monopolize the American market for German products. Obviously, the seizure of these patents and their administration for the benefit of the American people was indicated.

For this purpose The Chemical Foundation was incorporated as a non-profit-making organization, with Mr. Garvan as president. Such income as might accrue to the organization was to be employed "for the advancement of chemical and allied science and industry in the United States."

Immediately it became apparent that we were faced, not only with the tasks of building up a war-time chemical industry and of laying the foundations for its continuation in peace, but with the necessity of undertaking a nation-wide educational campaign. The American people in general had little or no conception of the functions and significance of chemistry. In the minds of many, the science partook of the nature of a black art of which, appropriately enough, Satan's allies in the World War were the chief and most adept, if not the sole, practitioners. The superstition that only the Germans could produce dyes and drugs of first-class quality was widespread.

With Mr. Garvan as its guide and moving spirit, The Chemical Foundation undertook the task of enlightenment. In the course of this educational campaign more than twenty million pieces of literature, including over a million popular books on chemistry, were distributed. Likewise subsidies have been granted from time to time to: the JOURNAL OF CHEMICAL EDUCATION, *The Chemistry Leaflet*, *Journal of Physical Chemistry*, the *Sewage Works Journal*, *Journal of Rheology*, *Radiology*, *The American Journal of Cancer*, *The Chemist*, and *The Courier of the*

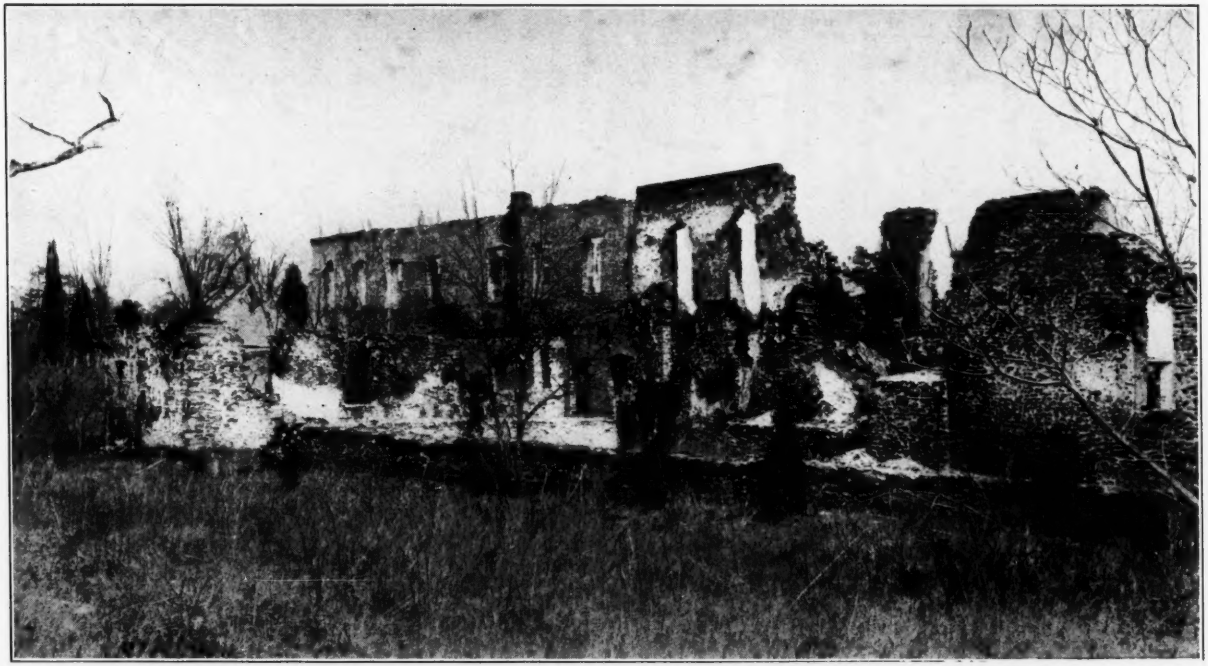
I. C. F. N. Other publications, including those of the Americal Chemical Society, have received various gifts for special purposes. In addition, grants for researches on cancer, tuberculosis, leprosy, heart trouble, and the common cold have been made to various institutions.

Supplementary to the educational and promotional activities of The Chemical Foundation, which are by no means completely cataloged here, Mr. and Mrs. Garvan originally suggested, and have since supported with their own private funds, the A. C. S. Prize Essay Contests. Through these contests thousands of students, over a period of eight years, have done extensive reading on the relationship of chemistry to modern civilization. Thousands of families have presumably read at least the essays of the contestants whom they harbored; many have read the literature employed in reference by the contestants. Hundreds of teachers have acquired a new vision of the importance and of the potentialities of chemistry.

Today the chemical industries constitute one of the soundest branches of the American economic structure. The daily and the periodical press devote a considerable amount of space to the sciences, chemistry among them. Even the oft-mentioned man in the street has some notion of what chemistry has done and considerable faith in what it may yet do.

But it is yet much too soon to estimate in full what has been accomplished. The leaven which has been implanted will continue to make itself evident for a generation at least. Already it is apparent that chemical industry and popular chemical education have acquired a start which promises to carry them forward with the constantly augmented momentum of the proverbial snowball.

The prize essay contests have done their part in a stupendous and worthwhile task, and have done it well.



RUINS OF A PAPER MILL AT HARRISVILLE, NEW JERSEY

Other views of the ruins and the floor plan of the mill may be found on pages 1924-5.

FRAGMENTS OF EARLY INDUSTRIES IN SOUTH JERSEY

K. Braddock-Rogers, University of Pennsylvania, Philadelphia, Pennsylvania

A brief description of the now abandoned industrial town of Harrisville, New Jersey, from 1760 to 1892 is given. A saw mill was the first venture and because this town was near several large bog iron ore furnaces a slitting mill was erected. The town reached the height of its development in the manufacture of paper from salt marsh grass. Allusion is also made to the attempted establishment of the silk industry in South Jersey. Numerous photographs and several maps and plans accompany the text.

. . . . . .

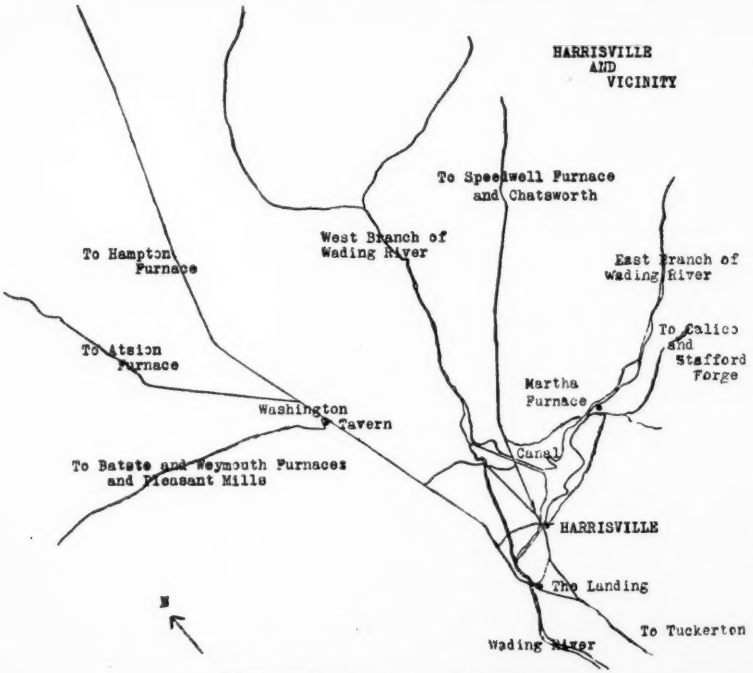
The Worldly Hope men set their Hearts upon
Turns Ashes—or it prospers; and anon,
Like Snow upon the Desert's dusty Face,
Lighting a little hour or two—is gone.
—Rubáiyát of Omar Khayyám

In the daily papers and the best magazines there are articles constantly appearing on the ruins of cities, temples, palaces. The mention of ruins turns thoughts to the old world and possibly very briefly to the wonderful ruins of the aborigines of the new world. The age of many of these ruins in both hemispheres counts into hundreds and even into thousands of years. Over such a great period of years the lay mind can readily grasp how the obliteration of evidences of civilization can take place. To conceive that a small town and industry in an industrial district may fold its tent and silently steal away in a few years after having functioned almost a century is well-nigh impossible.

In the southeastern corner of Burlington County of New Jersey on the East or Oswego Branch of the Wading River are the ruins of a once prosperous industrial town—the Wading River Slitting Mill of McCartyville or as it is now known to a few—Harrisville. It is a source of wonder today why a town and industry should ever have been started in such a country, which is desolation itself. It is in the midst of a fire-ravaged forest through which a few rutted sandy roads and many trails pass. There are no towns of any size near it—ten miles to the south lies Batsto of some dozen houses, and to the north Chatsworth with forty or fifty families. Scattered along the roads and through the woods there is a house now and then. A mile or two up the river are the remains of the once great Martha Furnace, now overgrown by the forest, and still farther away is Calico, marked today with a few half-filled cellar holes. Part way between Harrisville and Chatsworth is Speedwell with its two houses and one family. With the exception of the Forest Service Telephone Line the country is more primeval than when the Wading River Slitting Mill operated one hundred thirty years ago.

A century and a quarter ago this region was anything but desolate. It was the home of many industries (*1*). Batsto with its thousand inhabitants

had its famous iron furnace, glass works, and charcoal business; Atsion, Speedwell, Martha, Chatsworth, and Hampton with their iron furnaces and forges were all within a twelve-mile radius; grist mills, saw mills, turpentine stills, were everywhere; the making of shingles and barrel staves from the unlimited supply of red cedar was very profitable, as were charcoal burning and hunting. With so many industries there was of necessity much travel between the various towns. At that time there were two famous roads—one still used today, the other now almost impassable.

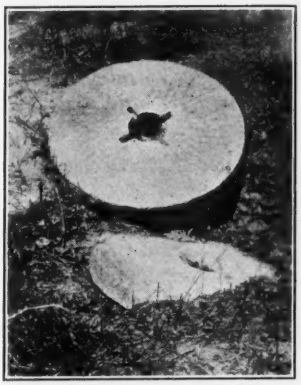


MAP OF HARRISVILLE AND VICINITY

The former road and its branches connected the great industrial towns of Weymouth, Pleasant Mills, Batsto, Speedwell, Chatsworth, and Pemberton. The latter road was the stage road from Tuckerton to Philadelphia over which the stage and mail coaches passed twice weekly. The remains of these roads are but slightly used now, but at the beginning of the nineteenth century they were much traveled.

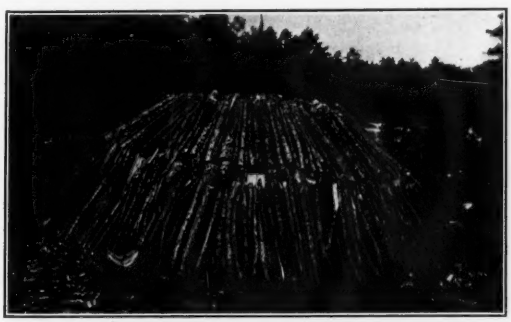
In an article, "The Bog Ore Industry of South Jersey Prior to 1845" (*1*), on page 1497 this statement is made: "The author has it on good authority that charcoal is still made in the Jersey woods as it was made over a hun-

dred years ago." He wishes to amplify this statement. After much diligent search through the woods he found in June, 1930, a partly completed cone for charcoal burning. Nearby were the remains of several other cones which had been burnt last season. The photograph shows this cone very clearly.



WHEELS OF GRIST MILL (1758) AT MARTHA FURNACE
Uncovered by W. S. Pettit and K. Braddock-Rogers

Isaac Potts, who it will be remembered was the owner of the Martha Furnace (*1*), sold 350 acres of his holdings for $20,000 in 1797 to Geo. Ashbridge, Morris Robeson, John Paul, and Charles Schomaker, merchants of Philadelphia, and later owners of the Weymouth Furnace. This particular tract was long known as the Wading River Slitting Mill. In 1805 the owners sold their interest to Joseph Walker and John Youle, the then owners and operators of the Speedwell Furnace, who further increased their holdings by the purchase of Evi Belangee's saw mill. Walker and Youle operated the slitting mill for ten years and then sold the property to the New York Machine Company. Numerous transfers of this tract took place until it came into the possession of McCarty, Davis, and Ashmead. It was bought by them in 1832 for $7000. Up to this time deeds of transfer had called in general for "....the slitting mill tract with all buildings, houses...." Four years later Wm. McCarty sold his controlling interest in the paper mill to the Wading River Manufacturing and Canal Company which was incorporated by the State of New Jersey in February, 1836. The capital stock was $200,000 and the directors were Wm. McCarty, Thomas Davis, Henry C. Carey, Isaac Lea, and Laurence Johnson. "..." to make paper, boards, and other articles," and "authorized to construct a canal from their land to some point on the tidewater of said River," and "....to



PARTIALLY BUILT CONE OF PINE LOGS FOR CHARCOAL
June, 1930

charge a toll of eight cents per ton per mile." The sale price of the transaction was $55,750 and the deed now calls for, "....mills, water courses, water-works, machinery, apparatus, houses, erections, buildings, woods, ways, dams, ponds, gates, rights...." Obviously, from the differences in price and the specifications in the deed McCarty and his associates must have greatly enlarged the entire plant. Nowhere in the vicinity of the ruins is there evidence of a canal to tidewater of the Wading River and no information regarding this has come to the author.

McCarty seems to have been associated with the cotton mill at Pleasant Mills before he went into business for himself. He called the Slitting Mill tract McCartyville and started the manufacture of paper to which further reference will be made. In 1848 the Mill came into the possession of John W. Harris who operated it for a number of years. In 1865 the Harrisville Manufacturing Company was incorporated by the State of New Jersey with a capital stock of $500,000 and R. C. Harris, H. P. Harris, C. Heinerman, W. Woodfall, J. S. Fisher, and A. E. Smith, directors. The plant controlled by the Harrises continued to operate until 1892 when it shut down forever, due to a variety of circumstances, both economic and financial.

Evi Belangee, to whom reference has been made, appears to have been the first to make use of a natural depression of the country. A horizontal cross-section of this depression through which that section of the Wading River flows resembles a bottle formation. This bottle is one and a half miles long and three-quarters of a mile wide at the base. It gradually tapers to a width of seventy-five to one hundred feet at the mouth. It was at the mouth of this bottle that Belangee built a dam for his saw mill about 1760 or before. It is known that the dam was not very large and judging from the very slight evidence which exists today the head was perhaps five or six feet. The dam was enlarged when the Slitting Mill was built and with the arrival of McCarty this dam was again enlarged to give a head of ten to twelve feet and still further enlarged by Harris to give a head of fifteen to sixteen feet.

Six years ago in a marsh which is some little distance from the site of Belangee's mill there were dug up cedar planks in an almost perfect state of preservation. These planks were used in the sheathing of a building. This is very reminiscent of an interesting phase of the lumber industry which was practiced in the cedar swamps of South Jersey over a hundred years ago. While somewhat of a digression from the main topic it is worthy of notice since few people ever heard of such a practice.

Excerpts from a Description of the Great Cedar Swamps

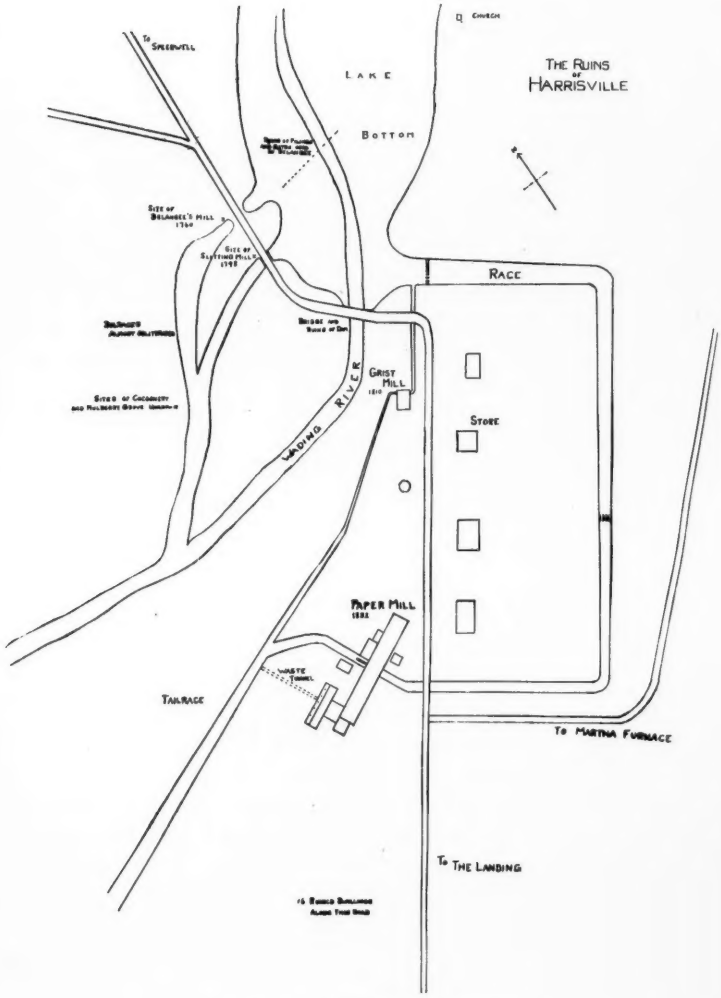
Very few trees are known which are more than one hundred years old, and the swamps are now cut off when the timber is of about sixty years' growth. Formerly trees of great age were found. Mr. Charles Ludlam counted 700 rings of annual growth in a tree which was alive when cut down. Dr. Beesly counted 1080 in a stump; and the Hon. J. Diverty

found 1000 in a log dug up out of the swamp earth. The average size of the old trees was from two to three feet in diameter; those of four, five, and six, even seven, feet were found, but rarely. Mr. Charles Ludlam told me that he recently found a log in the swamps which, from its cut ends, he was satisfied had lain there ever since the timber had been cut off, which was sixty years ago. It was about a foot in diameter, and the accumulation of matter on the surface since that time was enough to entirely bury it. Timber which is buried in the swamp undergoes scarcely any change; trees which are found several feet under the surface, and which must have lain there hundreds of years, are as sound as they ever were; and it would seem that most of the timber that was ever grown n these swamps was still preserved in them.

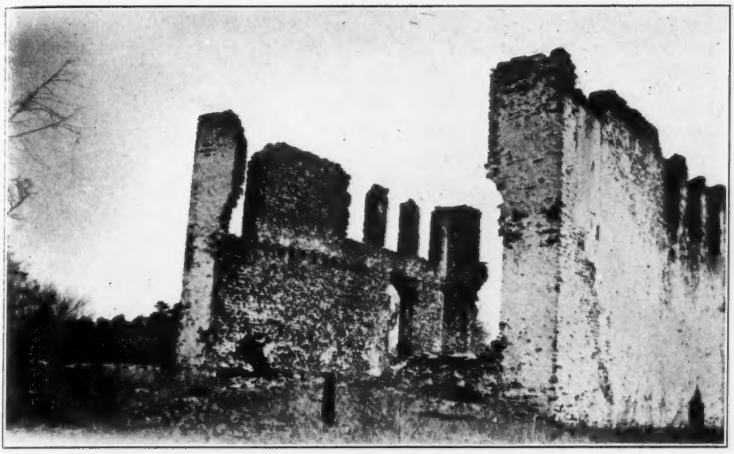
The cedar logs which are buried in the swamps are also mined, or raised and split into shingles; and this singular branch of industry furnishes profitable occupation to a considerable number of men. In conducting this latter business a great deal of skill and experience is requisite. As many of the trees were partly decayed and worthless when they fell, it becomes important to judge of the value of the timber before much labor is wasted upon it. With an iron rod the shingler sounds the swamp until he finds what he judges to be a good log; he tries its length and size with this rod; with a sharp cutting spade he digs through the roots and down to it; he next manages to get a chip from it, by the *smell* of it he can tell whether it was a *windfall* or a *breakdown*.

It is very interesting to see one of the logs raised. It comes up with as much buoyancy as a freshly fallen cedar; not being water logged at all. The bark on the under side looks fresh, as if it had lain but a few days; and what is remarkable, the under side of the log is always the lightest; the workmen observe that when the log floats in water it always turns over, the side which was down coming uppermost. The workmen go over the ground again and again, and find new logs each time. The buoyancy of the timber remaining, it is probable that the lower logs rise in the mud when the roots over them are cut loose, and the logs which laid upon them are removed. These logs are found not only in the swamp, but also out in the salt marsh, beyond the living timber. Such marsh has, however, a cedar swamp bottom, which has been overrun by the tide.

The ruins of Harrisville stretch along the road for a quarter of a mile. About twenty-five buildings or groups of buildings are in the ruins—ranging from the merest outlines of cellars to the major ruins of the paper mill, grist mill, and store. A pile of stones marks the site of a church and two large partly filled-in cellar holes are the sole reminders of two splendid dwellings. One of the most curious of the ruins is an eight-sided building. The stone work extended eight feet above the ground; it has six-foot sides, one of which was the door, and evidently a wooden roof. Most interesting uses have been assigned to this building by well-meaning people who on good authority say that it was a prison, a gas house, an observatory, a spring house, and finally a blockhouse to be used against Indians. The accompanying illustration (p. 1922) shows this queer structure which was totally destroyed on September 2, 1930.



MAP OF THE RUINS OF HARRISVILLE



RUINS OF STORE AT HARRISVILLE

The best idea of the paper mill can be had by referring to the floor plan which is given in the illustration on page 1925. The central part of the building was built by McCarty and enlarged by Harris. The western wing was built by the former, while the eastern wing and most of the other sections were built by Harris. All of the buildings are built of ironstone which came from the nearby bogs, for it must be remembered that this is in

RUINS OF THE GRIST MILL AT HARRISVILLE

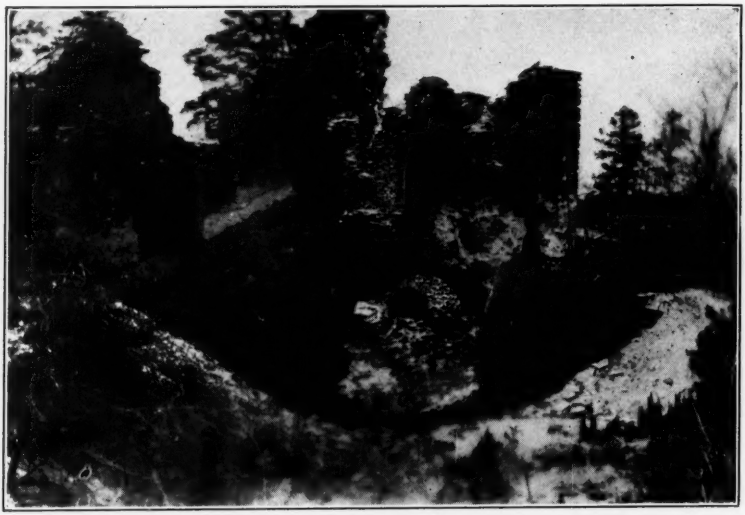
the very heart of the bog ore district. The walls of the main building are three feet thick, while those of the additions vary from eighteen inches to two and a half feet thick. The mill proper is three hundred feet long, thirty-eight feet wide, and over thirty-five feet high. The size of the various sections and the additions can be easily estimated from the floor plan. The two archways which can be seen in the picture (page 1925) are thirteen feet apart and the same in width. The entrance of the race into the building which was directly opposite the pier between the two arches is completely destroyed but from the dimensions of the race it must have been at least fourteen feet wide and fifteen feet deep.

OCTAGONAL BUILDING OF UNKNOWN USE

This pen and ink sketch was made from a very poor photograph which was taken just before the building was destroyed.

The canal system for the handling of the water requires special mention. The dam to which allusion has been made backed the water almost to the Martha Furnace —two miles away on a straight line. The breastworks of the dam are only one hundred feet long while a few hundred feet from the dam itself the width of the artificial lake was almost one thousand feet. From the south bank and quite close to the dam a small race was dug one hundred and twenty-five feetlong, five feet deep, and four feet wide to lead the waters to the grist mill. McCarty dug a race which was seven hundred and fifty feet long with arms four hundred and fifty feet in length. It was dug by hand labor at the reported cost of three cents a cubic yard. This race carried the water from the lake to the paper plant and then from there by means of a sluice, likewise artificial, to the river one thousand feet away. Harris enlarged the canal, when he purchased the plant, to a width of thirty feet and a depth of seven feet. A hundred feet from the mill the race tapers to twenty-two feet in width and then to fourteen feet in width and twelve feet in depth at its entrance into the mill. With this enlargement of the race, Harris found it necessary to increase the water supply of

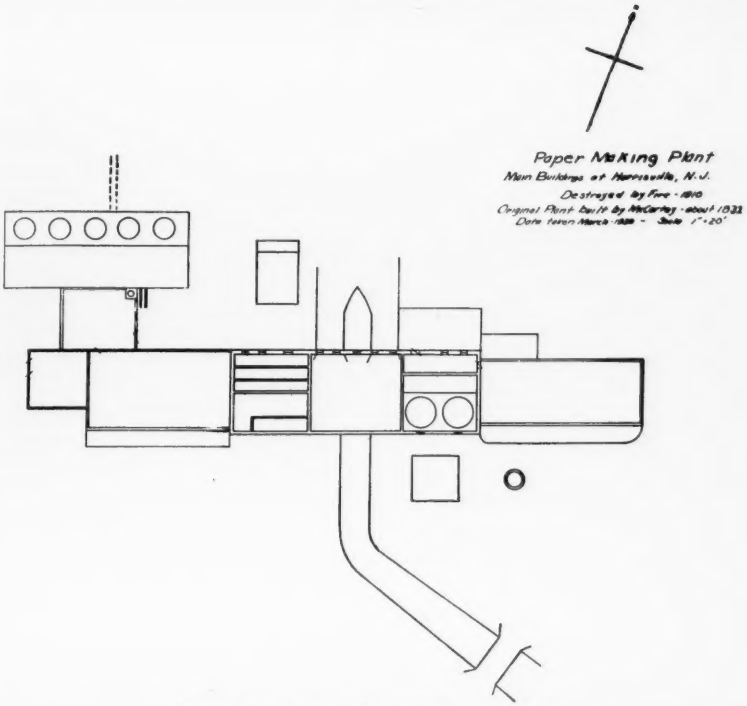
TWO VIEWS OF THE WATER RACE FROM THE LAKE TO THE MILL



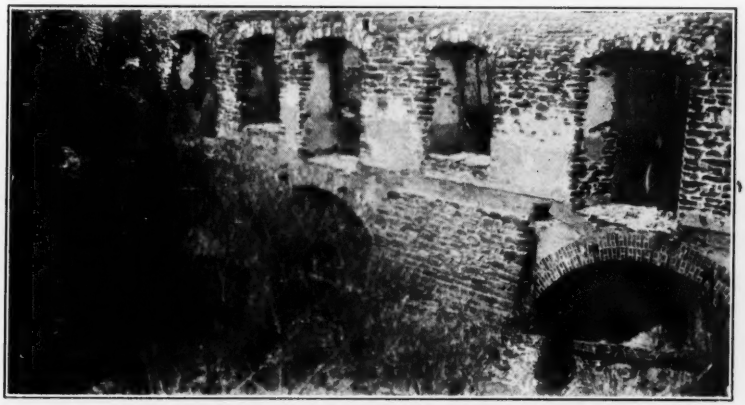
MOUTH OF RACE INTO GRIST MILL

the lake. Accordingly he had dug in 1865 a canal to divert the waters of the west branch into the east branch of the Wading River. The mouth of the canal was at a bend in the river where eight-feet gates diverted the waters. This canal, which is one and three-eighths miles long, follows a straight line in a general northwest-southeast direction. Whether by chance

RUINS OF THE PAPER MILL AT HARRISVILLE


Paper Making Plant
Main Buildings at Harrisville, N.J.
Destroyed by Fire - 1910
Original Plant built by McCarley - about 1831
Date taken March 1888 - Scale 1"=20'

PLAN OF THE PAPER MILL AT HARRISVILLE



ARCHWAYS LEADING INTO TAILRACE—MAIN BUILDING

LAKE BOTTOM FROM BREASTWORKS OF DAM
June, 1930

or by design its course was so carefully surveyed that it gave a head of six feet, which is the maximum obtainable from the natural topography of the district. The canal empties into the lake three-quarters of a mile above the dam.

A quarter of a mile down the west branch of the Wading River from the point where the canal starts can be seen the dim outlines of a sluice and raceway, the remains of an embankment, and the pilings of the dam and the gates. It is the remains of probably the first industrial attempt of the district. It was known as the Skit Mill and was built in 1750, as a grist and saw mill which is said to have functioned for seventy-five years. The photograph (p. 1928) shows the remains of the dam and the pilings.

The raw materials which were used in construction and in the business were all at hand. All of the buildings, the dam, the facings of the sluice raceways were made of ironstone. There is some brickwork about the arches of the race but it is insignificant in amount in comparison with the other construction. The wood for construction and firing came from the neighboring forests, the ironwork for the buildings from the nearby furnaces, power and water from the Wading River. The raw material for the paper was marsh grass from the marshes of the Mullica River. It was bought for three dollars a ton and was brought to the mill landing on twenty-ton barges, from the landing to the mill by mule team.

CANAL LOOKING SOUTHEAST

From the barges the marsh grass went to the cookers. These were in a shed whose floor level was several feet below the surface of the ground and it held five vats, ten feet in diameter. Live steam was forced into

Canal Looking Northwest

these vats, which leached out the salts and soluble material. The condensing steam and wash liquors were run off through a tunnel to the sluice. The grass then went to the large stone vats fifteen feet in diameter and there it was chopped up by vertically revolving knives into a pulp. From the macerators the pulp was pumped to a storage tank where it was very slowly agitated to keep it from packing. This storage tank was a deep well, lined with ironstone and built above the ground about ten feet; it was twenty-two feet square. The pulp was then ready to be made into

The Remains of the Pilings of the Floodgates and Beginning of the Canal Embankment Which Diverted the West Branch into the East Branch of the Wading River

SITE AND RUINS OF THE SKIT MILL DAM

paper. In later years a building in which were two drums with knives was built. The drums slowly revolved to cut the grass which was then allowed to drop into another tank. From the construction of the building it is easy to see that it is of a very much later date. The walls have stones of mica schist and calcite while the brickwork is far superior to that in the original arches. Certain it is that these stones never came from South Jersey and in all probability were transported there as ballast on a ship. The paper is said to have had great tensile strength and to have been of a peculiar brown color. This color was due to the iron in the water which was used, for it must be remembered that the Wading River flows through and helped to lay down the enormous limonite deposits. Many attempts were made at the plant to make a white paper but all failed. The finish was put on the paper by passing it very slowly over a roller where it was buffed by another roller going in the opposite direction and at considerable speed. The finished paper was loaded on barges at the landing and floated down the river to the ships for transportation to New York and Philadelphia. In later years the paper was hauled by mule and ox team through the woods to Harris Station on the railroad (which is now the Central Railroad of New Jersey) from where it went directly to New York.

About 1830–40 much enthusiasm developed in South Jersey over the silk industry. Many attempts were made to raise silkworms and to develop the silk industry. Harrisville was one of the places where the industry was attempted on a large scale which, however, only reached the experimental stage. There was a large mulberry tree grove planted and a building was put up as a cocoonery. The building long ago disappeared, the mulberry

trees, all but a few straggling stumps, have been burned in the several fires and the industry and silkworms died a natural death.

It is not the purpose of this paper to go into the reasons both real and fancied for the decline of Harrisville. A very interesting story has come to the author from the pinies who live in the vicinity. They say that nothing can ever grow or exist in South Jersey. They cite the many industries which have failed in a century and a half. This has happened because almost everything is built of ironstone and that coupled with the iron deposits in the swamps attracts the lightning which is so severe that it frightens the people, who immediately leave the country. If they do not leave the lightning strikes and destroys everything.

The ruins of Harrisville are slowly becoming more and more obliterated. The buildings are crumbling, the canals are filling up, trees and vegetable growth are steadily overgrowing everything. Coupled with the forces of nature are the damaging visits of the summer week-end picnickers who scatter about trash and débris of every description—even to the pollution of the spring. During the week Harrisville exists in utter desolation, nothing can be seen but ruins, burnt forests, and scrub second growth. To intensify the solitude of the place are the scores of deer tracks in and about the ruins and along the raceway, lizards scurry through the tumbled rocks of the ruins, and an occasional pine snake lazily glides over a broken wall and into the brush. And as Harrisville is slowly but surely departing from the ken of man, the beautiful white water lily in the sluice and in the race slowly opens and closes, watching and waiting for the day when once again it will reign unmolested and supreme in the South Jersey wilderness.

The Moving Finger writes; and, having writ,
Moves on: nor all your Piety nor Wit
Shall lure it back to cancel half a Line
Nor all your Tears wash out a Word of it.

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The author wishes to express his appreciation to the many friends who assisted him in the preparation of this article. Particularly to Mr. J. K. Simons, Chemistry Department, and Professor W. H. Barton, Civil Engineering Department of the University of Pennsylvania, is the author indebted, and finally to his wife for her unfailing interest and helpful criticisms.

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How difficult it is to obtain the triumph of truth! Opposition is a useful stimulant, but bad faith is such a pitiable thing.—PASTEUR

WHAT IS PETROLEUM?
METHODS FOR THE ISOLATION AND DETERMINATION OF THE CHEMICAL CONSTITUENTS OF PETROLEUM*,**

JOHANNES H. BRUUN,† U. S. BUREAU OF STANDARDS, WASHINGTON, D. C.

This paper is a brief description of the methods which have been developed or improved for the purpose of separating complex mixtures, such as petroleum, into individual chemical constituents. Because of the presence of compounds which form constant boiling mixtures and of many isomeric hydrocarbons with nearly the same boiling points, a complete separation of petroleum cannot be obtained by fractional distillation alone, even if rectifying stills of the highest efficiency are used. By interlocking distillation with fractional crystallization and fractional extraction, however, it has been found possible to isolate a number of pure hydrocarbons. At the end of this paper a description is given of the actual isolation and identification of some of the constituents of a Mid-continent petroleum.

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Introduction

Petroleum constitutes one of the greatest natural resources of the North American continent. About three-fourths of the world's petroleum is produced in the United States, where billions of dollars have been invested in the petroleum industry. Chief among the numerous products which are manufactured from petroleum are fuels, lubricants, solvents, waxes, asphalts, and various types of oils.

Crude petroleum and its products are complex mixtures consisting of a great number of different constituents. For more than sixty years different investigators have studied the composition of petroleum. In spite of this fact our knowledge of the composition of petroleum and products obtained from it is still extremely limited. The presence of many individual hydrocarbons has been indicated and in some cases proved by chemical methods. It has been possible to show that petroleum is a complex mixture, consisting of aliphatic, cyclic, and aromatic hydrocarbons, many of which are present in numerous isomeric forms. With the exception of a few of the lowest boiling fractions, however, it has been considered practically impossible to separate these complex mixtures into their in-

* Publication approved by the Director of the Bureau of Standards of the Department of Commerce.

** This paper describes some of the results obtained in an investigation on The Separation, Identification, and Determination of the Chemical Constituents of Commercial Petroleum Fractions, listed as project No. 6 of the American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by John D. Rockefeller. This fund is being administered by the Institute with the coöperation of the Central Petroleum Committee of the National Research Council.

† Research Associate, American Petroleum Institute.

dividual constituents and to obtain reliable quantitative data concerning their composition.

While several million barrels of petroleum are handled daily by the oil industry, the prevailing absence of analytical methods is responsible for a complete lack of information concerning the composition of the raw material as well as of the finished products. It is evident that due to this situation the petroleum industry has failed almost entirely to utilize for synthetic purposes this greatest source of natural raw material. In view of these facts an investigation was started at the Bureau of Standards in 1926 for the purpose of developing methods for the determination and separation of the chemical constituents in petroleum fractions. In January, 1927, the investigation received the support of the American Petroleum Institute. The staff engaged in this project, which is under the direction of E. W. Washburn, Chief of the Chemistry Division of the Bureau of Standards, consists at present of six research workers and six still operators.

In this paper, a brief description of some of the methods which have been developed or improved during the work on this project is given. Also, the actual isolation of some of the chemical constituents of a Mid-continent petroleum is described.

Methods Employed

In order to separate the numerous complex mixtures of petroleum into their chemical constituents efficient methods of fractionation are required. In the present investigation, combinations of the following methods have been employed: fractional distillation, fractional crystallization or melting, fractional extraction with solvents, and in some cases chemical methods.

Distillation Methods

A LABORATORY BUBBLING CAP STILL OF STEEL FOR THE PRELIMINARY DISTILLATION OF PETROLEUM FRACTIONS

An effective separation of petroleum by fractional distillation can be accomplished only by using distilling columns of very high efficiency. Figure 1 shows a section of a bubbling cap column (*1*) which has been used for the 20-liter laboratory still. The object of a bubbling cap column is to force the ascending vapor in the column into intimate contact with the reflux liquid and thereby increase the efficiency of the distillation. This is accomplished in the following way: In Figure 1 (in which a cross-section of the upper plate is shown) the vapor from the still pot follows the arrows, passing up through the opening in the center of the plate, then down along the inside wall of the "bubbling cap." Near the bottom of the bubbling cap the vapor is forced out through a series of small holes. The liquid on

the plate (formed by previous condensation of vapor) is thoroughly agitated by the stream of fine bubbles passing through it. When condensed liquid fills the plate above a certain level, the excess overflows (down to the plate below) through *B*. In this way a very intimate contact is effected between the ascending vapor and the descending liquid, before the vapor finally leaves the top of the bubbling cap column.

A laboratory bubbling cap still of steel has been built by combining 20 bubbling cap plates of the type shown in Figure 1 into a column. This distillation apparatus (*2*) is shown in Figure 2. The still was developed in order to carry out efficiently the first distillation of the petroleum fractions. Because the higher hydrocarbons have a great tendency to oxidize and decompose ("crack") when heated in the presence of air the distillation is carried out in an atmosphere of carbon dioxide (*3*). In Figure 2 the oil to be distilled is introduced into the still pot, *8*, through a filling device, *24*. The carbon dioxide from the storage cylinder, *1*, passes through drying tubes, *2*, and past the flowmeter, *3*, and then through a pyrex glass tube, *4*, filled with copper shavings and heated electrically to 650°C. (Preliminary experiments showed that at this temperature all traces of oxygen are removed from the carbon dioxide.) After passing by a manometer, *5*, and a safety valve, *6*, the gas enters the still pot, *8*, through the copper tube, *7*. This tube is bent at the bottom to form a large ring which is perforated so as to break up the gas flow into numerous streams of fine bubbles. The fractionating column, *9*, contains 20 bubble cap plates. At the top of the column a final separating device, *10*, (dephlegmator) is located. The temperature of the dephlegmator is con-

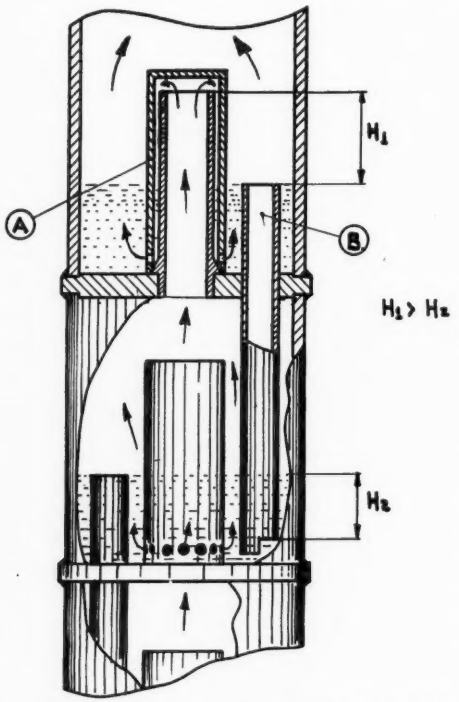

FIGURE 1.—LABORATORY DISTILLING COLUMN WITH BUBBLING CAP PLATES OF STEEL

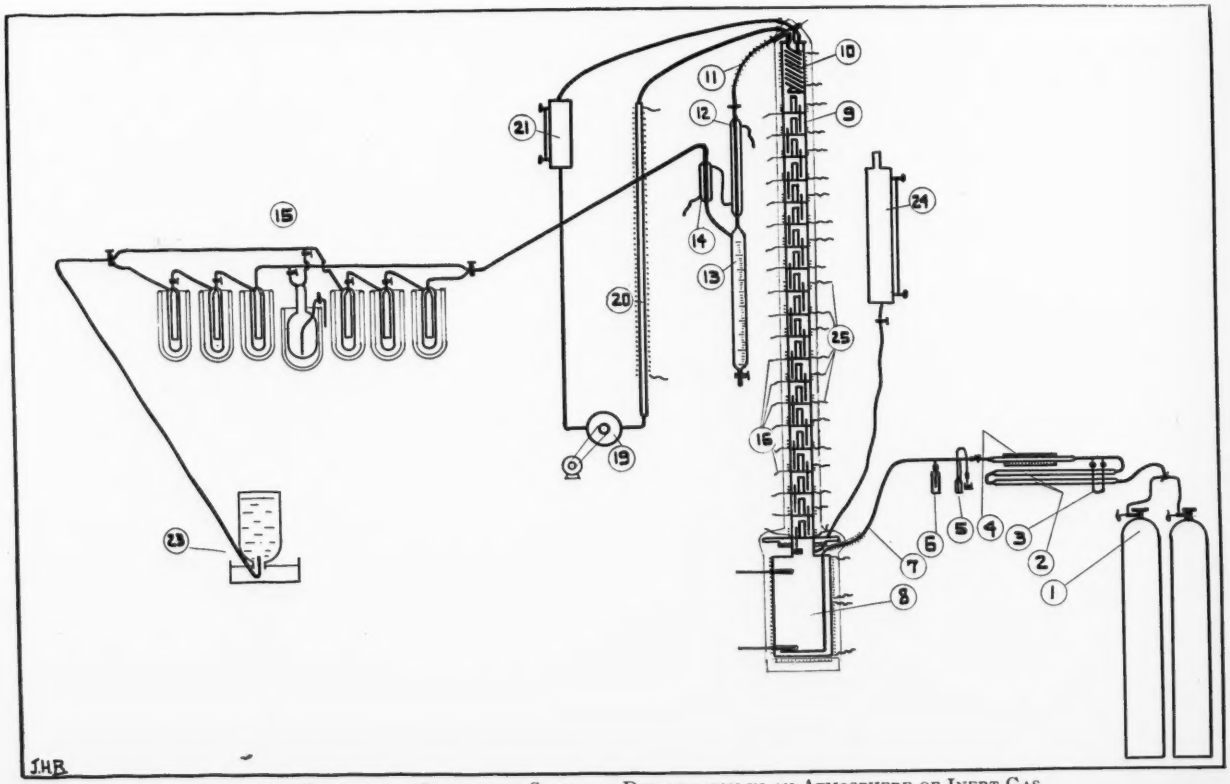

FIGURE 2.—LABORATORY RECTIFYING STILL FOR DISTILLATION IN AN ATMOSPHERE OF INERT GAS

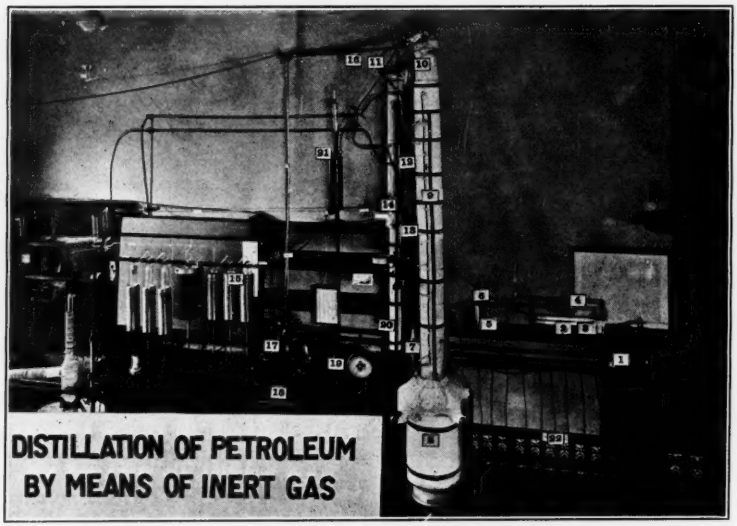

FIGURE 3.—LABORATORY RECTIFYING STILL FOR DISTILLATION IN AN ATMOSPHERE OF INERT GAS

trolled by internal copper coils through which oil of desired temperature is circulated by means of a special pumping and heating system, *19*, *20*, and *21*.

The hydrocarbon vapors and the carbon dioxide after leaving the column pass through the copper tube, *11*, and the condenser, *12*, into the graduated receiver, *13*. From the top of this receiver the carbon dioxide passes up through the condenser, *14*, and into a series of low-temperature condensers, *15*, in which low-boiling hydrocarbons are condensed. The carbon dioxide is finally absorbed in potassium hydroxide solution, *23*.

The still pot is heated electrically and the temperature of the column is regulated by means of twenty independent heating coils, *25*, and thermocouples, *16*.

The photograph in Figure 3 shows an assembly of the rectifying still.

LABORATORY BUBBLING CAP STILLS OF GLASS FOR THE FINAL DISTILLATION OF THE PETROLEUM FRACTIONS

Figure 4 shows a section of a newly developed bubbling cap column of pyrex laboratory glass (*1*). The ascending vapor from the still pot enters the column through the tube, *A*, at the bottom. It follows the path of the arrows, passing up through the tube, *B*, in the center, then down along the inside wall of the loose bubbling cap, *C*. At the bottom of the cap the vapor is forced through some narrow slits, in a stream of fine bubbles, in

order to insure good contact between the vapor and the condensed liquid on the plate. When condensed liquid fills the plate above the point, *D*, it overflows through the side arm, *E*.

The column has been made in diameters of 12 mm., and 20 mm., and 28 mm. and with 2 to 61 plates.* The photograph in Figure 5 shows five stills with bubbling cap columns of this type. These columns contain 30 plates each.

These glass stills are used for further distillations of those fractions obtained from the steel still shown in Figure 2. These fractions are distilled until their boiling ranges fall within a few tenths of one degree or less. However, this does not necessarily mean that their composition is approaching that of pure compounds, because in many cases constant boiling mixtures of cyclic and aliphatic or of aromatic and aliphatic hydrocarbons are encountered. In other cases the final distillates consist of two or more isomeric hydrocarbons, the boiling points of which may be practically identical. In cases like this a separation by means of distillation is, practically speaking, an impossibility and the other methods of fractionation (such as crystallization, extraction, etc.) must be employed.

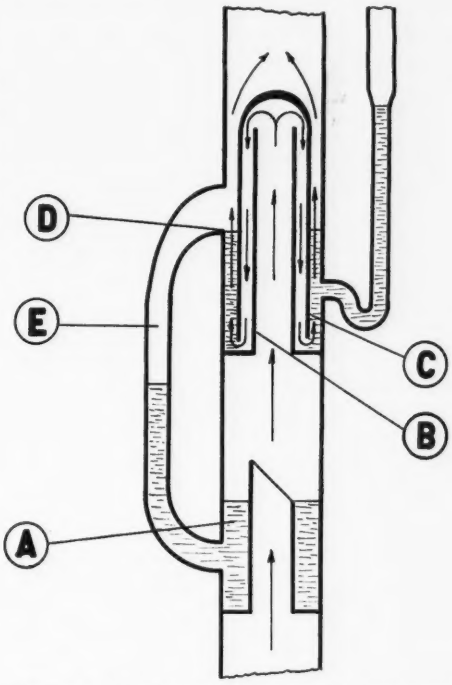

FIGURE 4.—LABORATORY DISTILLING COLUMN WITH BUBBLING CAP PLATES OF PYREX LABORATORY GLASS

MOLECULAR STILLS FOR DISTILLING HIGH-BOILING PETROLEUM FRACTIONS WITHOUT DECOMPOSITION

It is well known that many petroleum hydrocarbons in the higher fractions are extremely unstable even at the temperatures required for ordinary

* A complete description of these stills will be published in the near future.

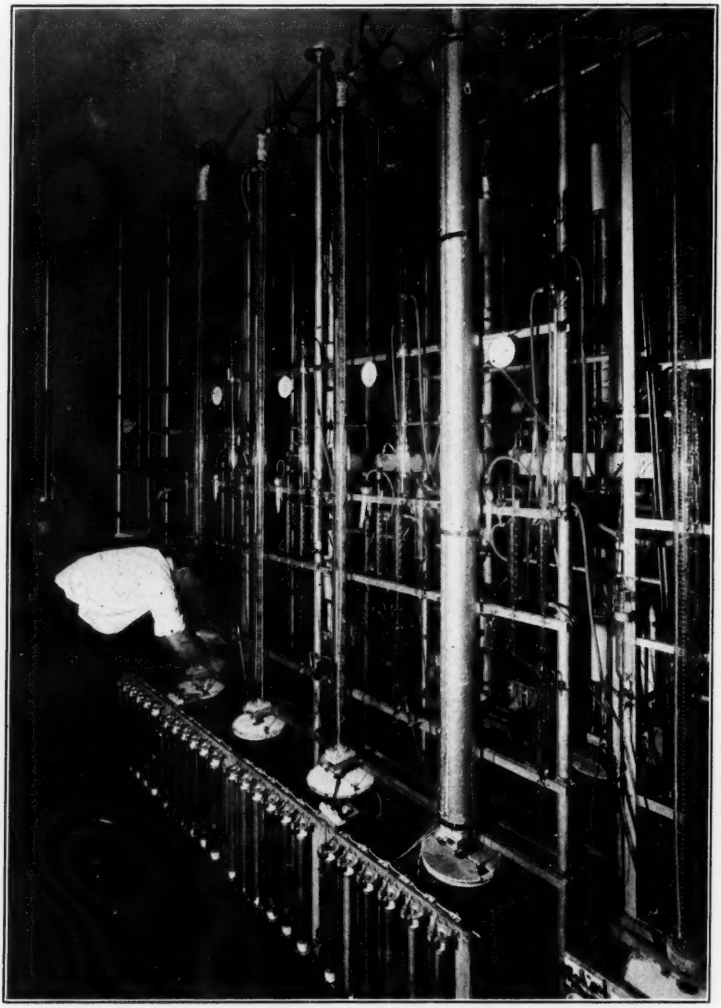

FIGURE 5.—ASSEMBLY OF SOME OF THE BUBBLING CAP STILLS (OF PYREX LABORATORY GLASS) AT THE BUREAU OF STANDARDS

vacuum distillations. For these hydrocarbons E. W. Washburn has developed the "molecular stills" (*4*), (*5*) by means of which low temperature distillations may be carried out without boiling. If necessary the temperature may even be maintained below the melting points of the hydrocarbons. Figure 6 illustrates the principle of the molecular still. The substance to be distilled is placed in the receptacle, *A*. The ground joint between the receptacles *A* and *B* is sealed tight, after which the inside of *A* is highly evacuated. As soon as air, moisture, and volatile impurities have been removed by the vacuum pump, the receptacle *A* is placed in a bath which is maintained at any suitable temperature, for instance 20°C. The receptacle *B* is now filled with liquid air (or some other suitable cooling agent) after which the distillate will start to condense on the outside wall of *B*. The fractions are collected by breaking the vacuum and removing the distillate.

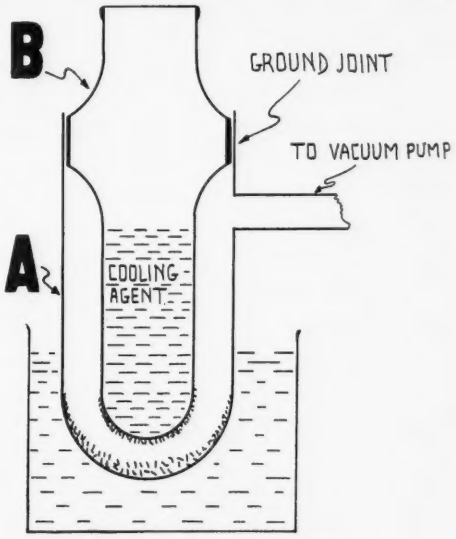

FIGURE 6.—MOLECULAR STILL

Contrary to the ordinary distillation, the fractionation in the molecular still depends not only upon the relative vapor pressures, but also upon the differences in the molecular weights of the constituents. Under a high vacuum, the mean free path is great enough to minimize collisions between the molecules. This results in a practically unidirectional distillation. Because of the fact that the rate of distillation (number of molecules leaving the surface per unit time) is considerably less than that at which the molecules diffuse to the surface, equilibrium between the molecules in the vapor and the liquid (or solid) phases will be maintained during the distillation.

Crystallization Methods

EQUILIBRIUM MELTING

For the purpose of breaking up constant boiling mixtures or mixtures of compounds having nearly identical boiling points, fractional melting (equilibrium melting) has been found to be a useful method of separation.

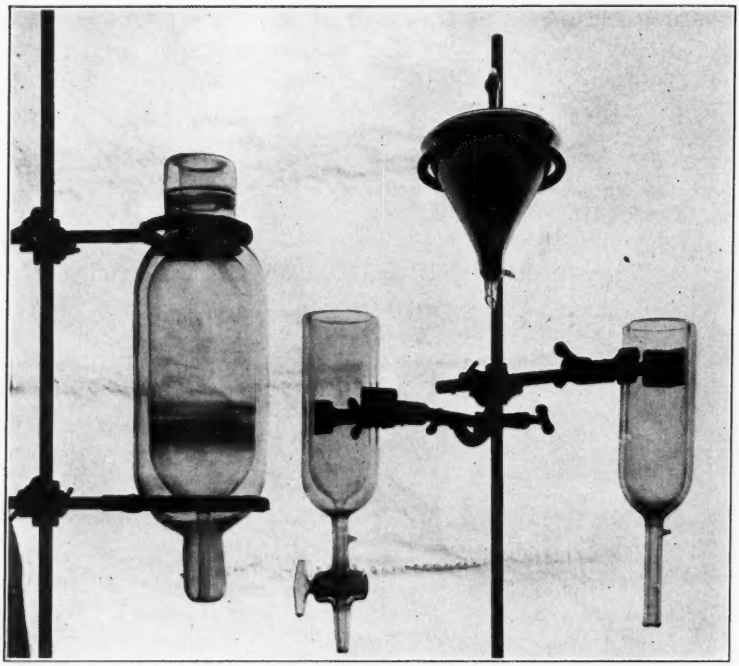

FIGURE 7.—VACUUM-JACKETED FUNNELS FOR FRACTIONAL CRYSTALLIZATION

For fractionation of petroleum hydrocarbons with low freezing points, the following simple method has been described by Mildred M. Hicks-Bruun (*6*): The hydrocarbons contained in a brass cylinder are completely frozen in a cooling bath (consisting of liquid air, CO_2-slush or any other suitable cooling agent). By slightly warming the walls of the cylinder, the solid hydrocarbon can be transferred easily to a vacuum funnel. Sintered glass filters (pyrex) are sealed into some of these vacuum-walled funnels (see Figure 7), while the usual extraction cups of filter paper or fine copper gauze are used in others. The frozen mixture of hydrocarbons is then allowed to melt slowly under constant agitation. In this way the lower melting material will be collected in the first fraction, while the higher melting substances will be obtained at the end of the fractionation.

More elaborate methods for fractional melting of larger quantities have been described by R. T. Leslie and S. T. Schicktanz (*7*).

CRYSTALLIZATION FROM SOLVENTS

The use of a solvent is often desirable for separating the constituents of the higher petroleum fractions, such as lubricating oil or wax. Of a great

many solvents which have been studied, ethyl ether was found to be one of the most suitable (*6*). The fractionation may be carried out by any one or more of the following methods:

1. By cooling the solution and subsequent removal of the separated "fractions."
2. By evaporating the solvent at any controlled temperature.
3. By precipitation with a second liquid.

Extraction Methods

Extraction methods depend upon the fact that many solvents possess the property of dissolving certain types of petroleum hydrocarbons (for instance, aromatics) to a greater extent than other classes (such as, for example, paraffin hydrocarbons). One of the determining factors with respect to the solubility of a hydrocarbon in a solvent is the similarity between the structures of the solute and the solvent. For instance: aniline, possessing an aromatic ring structure, may be expected to dissolve hydrocarbons of the aromatic series, such as benzene and toluene, more readily than those of the aliphatic series, such as hexane and heptane.

Different solvents, such as sulfur dioxide, aniline, xylene, etc., have been investigated and suitable types of extraction apparatus have been constructed. One of these (*8*) is intended for extraction with organic solvents such as aniline, xylene, and others, and has been used for the separation of benzene from petroleum.

For the purpose of isolating the chemical constituents of petroleum fractions, extraction methods may be successfully applied, if alternated with other methods, such as fractional distillation and crystallization.

Chemical Methods

Because of differences in chemical properties of some of the types of compounds, which are present in petroleum fractions, it is possible to isolate certain hydrocarbons by subjecting the fractions to suitable chemical treatments. In this way unstable or more reactive constituents are removed, while hydrocarbons possessing a greater resistance toward the chemical reagents will be only partly acted upon. Thereafter the remaining unattacked constituents may be subjected to fractionation and finally isolated. To methods of this type belong:

1. Treatment with fuming nitric acid (*9*)
2. Treatment with chlorosulfonic acid (*10*), (*11*), (*8*), (*7*)
3. Treatment with fuming sulfuric acid (*12*)

As quantitative methods, however, these are of little value because of their destructive effects upon all classes of hydrocarbons.

Another type of chemical method is represented by controlled nitration, by means of which it is possible (in the absence of olefins) to remove quan-

titatively certain aromatic constituents such as benzene (*8*) and toluene (*13*) without attacking the other hydrocarbons. By this method the aromatics are quantitatively converted into their nitro-derivatives, from the weight of which the percentage of the aromatics in the original crude petroleum can be calculated.

Identification of the Isolated Petroleum Hydrocarbons

When the fractionation of the petroleum hydrocarbons has been carried to a point where further separation (by means of distillation, crystallization, extraction, and other methods) ceases, the following physical constants are determined for each of the fractions isolated: boiling point, freezing point, density, refractive index, and in many cases molecular weight, hydrogen-carbon ratio, and critical solution temperature with aniline. The hydrocarbon is also "finger-printed" by photographing its absorption spectrum.

By comparing the observed physical constants with those given in the literature for synthetic hydrocarbons it is possible to identify most of the constituents of lower boiling points. However, most of the physical constants of the higher boiling hydrocarbons which exist in many isomeric forms have never been determined. This is due to the fact that many of these hydrocarbons have never been prepared synthetically in a pure condition. In the absence of reliable physical constants for the synthetic hydrocarbons the empirical formulas of the isolated petroleum hydrocarbons will be ascertained. A discussion on this subject has been published by E. W. Washburn (*14*). In order to determine the empirical formula of a hydrocarbon the molecular weight and the hydrogen-carbon ratio must be determined. A molecular weight apparatus (*15*) (of the Victor-Meyer type) has been developed by Mildred M. Hicks-Bruun. By means of this apparatus it is possible to eliminate to a large extent the effects of departure from the perfect gas laws, and an accuracy of 0.3 per cent in the molecular weight can be obtained. An organic combustion apparatus for determination of carbon and hydrogen within 0.05 per cent has been described (*16*).

For each of the isolated petroleum hydrocarbons the purity is carefully checked by determining the crystallization and distillation ranges, from the former of which the mole percentage of total impurities can be calculated (*17*).

Isolation and Determination of Some of the Chemical Constituents of Petroleum

n-HEXANE AND ITS ISOMERS (*18*), (*8*)

In the course of the investigation on an Oklahoma petroleum the following hexanes (C_6H_{14}) were isolated:

			Approximate Amount in Per Cent of the Crude Oil
(1)	$CH_3—CH_2—CH_2—CH_2—CH_2—CH_3$	*n*-hexane	0.5 or less
(2)	$(CH_3—CH_2)_2CH—CH_3$	3-methylpentane	0.18 or less
(3)	$(CH_3)_2CH—CH_2—CH_2—CH_3$	2-methylpentane	0.09 or less
(4)	$(CH_3)_2CH—CH(CH_3)_2$	2,3-dimethylbutane	0.04 or less

The isolation of these compounds was accomplished in the following way. The petroleum fractions with boiling ranges of 54 to 75°C. were subjected to a great many distillations in the stills described earlier in this paper. Because of the fact that constant-boiling mixtures between the hexanes and other compounds (such as benzene) were formed it was not possible to separate pure *n*-hexane or its isomers by ordinary distillation alone. For this reason the fractions were mixed with methyl or ethyl alcohol, and this mixture was then distilled. Because the alcohols and the hexanes form constant boiling mixtures with minimum boiling point, it was possible to collect most of the hexanes (mixed with alcohol) in the first fractions of this distillation, while ring compounds were concentrated in the higher boiling fraction. The hexanes were then separated from the alcohol by washing with water (hexane is insoluble in water).

By alternating ordinary distillations, distillations with alcohol, and crystallization methods it was finally possible to isolate the above-named isomers of hexane in substantially pure condition.

n-OCTANE (*7*)

n-Octane was first concentrated by fractional distillation. When the point was reached where further separation became slow the distillation was interlocked with crystallization. In this way large amounts of material consisting chiefly of *n*-octane were obtained. After a final distillation the *n*-octane was found to meet all the criteria for purity.

BENZENE (*8*) AND TOLUENE (*13*)

The following procedure has been found very convenient in order to determine the amounts of benzene and toluene in petroleum fractions. The petroleum fractions are at first fractionally distilled until all of the toluene has concentrated in the fractions boiling above 90°C. and all of the benzene in the fractions boiling below this point. The fractions containing the benzene are then nitrated (with a mixture of nitric and sulfuric acids) until the benzene is converted into its dinitro derivatives. From the weight of the separated dinitro-benzene the benzene content of the fraction (and of the crude oil) is calculated. Similarly the fractions containing the toluene are treated with nitrating acid until the toluene is converted to

2,4-dinitrotoluene, from the weight of which the toluene content is then determined.

The investigation of the Oklahoma crude oil produced some rather interesting results concerning the temperature at which the benzene and the toluene distil. Although the boiling point of benzene is 80.2°C., most of it was found in the fractions boiling around 69°C. Similarly, most of the toluene was found in the fractions distilling at about 98°C., instead of at about 110°C., which is the boiling point of pure toluene. The reason for this was the fact that constant-boiling mixtures with minimum boiling point are formed between the benzene and the hexanes, and between the toluene and other constituents.

Based upon the crude petroleum the benzene and toluene were found to be present in the following amounts:

Benzene	0.08 per cent
Toluene	0.33 per cent

If desired, benzene as well as toluene may be isolated from petroleum without converting them to their dinitro derivatives, by using extraction methods. A sample of pure benzene was obtained in this way by alternating extractions (by means of aniline at 0°C.) with equilibrium melting.

The accompanying table lists all of the hydrocarbons which have been definitely identified in the petroleum under investigation.

TABLE I

Hydrocarbons Isolated from a Mid-Continent Petroleum

Formula	*Name*	*Per Cent in Crude*
C_2H_6	Ethane	[a]
C_3H_8	Propane	[a]
C_4H_{10}	Butane	[a]
C_5H_{10}	Cyclopentane	[a]
C_5H_{12}	Pentanes (two isomers)	[a]
C_6H_6	Benzene	0.08
C_6H_{12}	Methylcyclopentane	1/5
C_6H_{12}	Cyclohexane	1/3
C_6H_{14}	*n*-Hexane	1/2
C_6H_{14}	2,3-Dimethylbutane	<1/3
C_6H_{14}	2-Methylpentane	
C_6H_{14}	3-Methylpentane	
C_7H_8	Toluene	1/3
C_7H_{14}	Methylcyclohexane	[b]
C_7H_{16}	*n*-Heptane	[b]
C_8H_{10}	Xylenes (mixture)	[b]
C_8H_{18}	*n*-Octane	1
C_9H_{20}	*n*-Nonane	1

[a] Not determined.

[b] Determination in progress.

Conclusion

A more thorough chemical knowledge of petroleum will be of immediate value to the producer of motor fuels and lubricating oils, because it will relieve the present lack of definite information concerning the chemical composition of the crude oil as well as of the finished products.

The possible future importance of the development of methods for the determination and isolation of the constituents of petroleum appears to be almost unlimited. While the oil fields constitute one of the greatest sources of organic raw materials in the world, their present utilization is limited mainly to fuels for internal combustion engines and to lubricants. Efficient methods for separating the constituents of petroleum may cause it to become one of the major sources of raw material, not only for many industrial products, such as dyestuffs and synthetic organic chemicals, but also for certain food products and medicinal chemicals.

Moreover, methods found useful for the analysis and separation of petroleum should also be applicable to petroleum prepared synthetically by hydrogenation of coal, as well as to many other complex mixtures of oils, fats, and waxes from both the animal and vegetable kingdoms. From such application a vast field of extensive and economic utilization may result.

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New Process Cheapens Production of Ultra-Violet Transmitting Glass. The development of a completely automatic process of manufacturing window glass of high ultra-violet transparency has made possible the production of this glass in quantity at about one-fourth the cost under old methods, according to Donald E. Sharp, glass technologist, Hamburg, New York.

The new process has been installed in a large commercial plant in which during the first month of operation under the new system, approximately 200,000 square feet of ultra-violet transmitting glass were manufactured. Production for the remainder of the year is expected to reach nearly 2,000,000 square feet.

While methods of making ultra-violet transmitting glass have been known for years, Mr. Sharp explained, it has been possible to make glass of workable commercial quality only in relatively small amounts with much hand labor and at great cost. Although glass made under the new process still costs two or three times as much as ordinary glass, it is cheaper than plate glass and about 75 per cent less than it was six months ago.

Technical difficulties involving composition, crystallization, and annealing are overcome by the new process, Mr. Sharp stated. It was explained that a special variation of the Fourcault window glass system, which permits the drawing of large, continuous sheets, is used. As is generally known, this glass must be almost entirely free of iron.

"Up to the present, attempts to make ultra-violet transmitting glass in this country by automatic means have resulted only in the production of glasses which in ordinary thickness had an ultra violet transmission of only two or three per cent for the ultra-violet wave length known as 302 millimicrons. The new process produces a glass that will transmit permanently through the standard thickness of about eight one-hundredths of an inch, more than fifty per cent of the ultra-violet light it receives from the sun."—*Science Service*

Oldest American Newpaper Still Well Preserved. Though yellow with age, specimens of America's first newspaper, *The Boston News Letter*, have retained their strength and pliability during the more than two centuries since they were printed in 1704, tests made at the U. S. Bureau of Standards reveal.

Hemp and jute fibers were the chief or sole materials used in the manufacture of these time-defying old papers, it was discovered on chemical analysis.

History records the use of hemp in paper making by the Moors as early as 1178, the report stated.—*Science Service*

THE MIRROR OF ALCHEMY OF ROGER BACON

Translated into English

By

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The Speculum Alchemiae *or* Mirror of Alchemy *which is ascribed to Roger Bacon (1214–1292) is probably not the work of that man, but does belong to his time, and was held in as high repute by later alchemists as if he had written it. It appears to be a paraphrase of an earlier Arabic treatise on alchemy, or a summary of a number of such treatises. Portions of it are identical with portions of Avicenna's* Little Book of the Mineral Stone. *It sets forth the Sulfur-Mercury doctrine of the composition of the metals in a manner which makes it clear that the author was acquainted experimentally with the substances. It describes the alchemical process in which the materials are heated in a tightly closed vessel, gently at first and then more strongly, which process, curiously or perhaps significantly, is the same as that described by the Chinese alchemist, Wei Po-yang, in the second century A.D. The work was printed in Latin in the earliest printed books on alchemy, was later translated into the various European languages, and still had currency and authority as late as the eighteenth century.*

TRANSLATION

THE ALCHEMICAL TRACT OF THE VERY LEARNED MAN ROGER BACON

which he entitled

THE MIRROR OF ALCHEMY

Preface.

In times past philosophers have been accustomed to speak diversely and in many modes in their writings, for they have left us this science, which is really nobler than all others, inwardly obscured with enigmas and vague expressions. I reject such negative procedure in desperation, altogether, and not without reason.

I admonish you therefore that you set your mind firmly on these seven chapters, more than on all the writings of others, and on the transformations of the metals which are contained in them, and that you revolve wisely the beginning, the middle, and the end in your heart. You will find such subtlety in them that your soul will be filled.

Chapter I. Concerning definitions of alchemy.

In many ancient volumes many writers have set forth definitions of this art, and it behooves us in this chapter to consider the intent of their definitions. Hermes says of this science, "Alchemy is a corporeal science, com-

posed simply from one and through the agency of one, which joins precious things to one another understandingly and effectively, and converts them by natural commixture into things of a better sort." A certain other says, "Alchemy is the science which teaches how to transform any kind of metal into another"—and this is done by the use of the proper medicine as is apparent in many books of the philosophers. Alchemy, therefore, is the science which teaches how to make and to generate a certain medicine, which is called *elixir*, which, when it is projected onto metals or imperfect substances, perfects them completely at the moment of projection.

Chapter II. Concerning the natural principles and the procreation of minerals.

In the second place I will make a full declaration of the natural principles and of the procreation of minerals. First, however, it ought to be noted that the mineral principles in mines are Quicksilver and Sulfur. The complex metals and all other mineral substances, of which the varieties are many and diverse, are procreated from these. I say that Nature always sets before herself as an object the perfection of gold and strives for it. But various supervening accidents transform the metals, as is set forth plainly in many books of the philosophers. For pure and impure metals are generated according to the purity or impurity of the prime two, that is, of the Quicksilver and of the Sulfur—and we have gold, silver, tin, lead, copper, and iron, concerning whose purity and impurity or unclean superfluity and defect the following may be accepted as true.

Concerning the nature of Gold: Gold is a certain perfect substance generated from pure, fixed, bright, and reddish Quicksilver and from clean, fixed, reddish, and incombustible Sulfur, and it has no defect.

Concerning the nature of Silver: Silver is a clean substance, pure, almost perfect, procreated from a pure, nearly fixed, bright and white Quicksilver and from a like Sulfur. It lacks a little fixation, and is defective in color and weight.

Concerning the nature of Tin: Tin is a clean but imperfect substance, procreated from a Quicksilver which is pure, fixed and not-fixed, bright, white in its manifest properties and reddish in those which are hidden, and from a like Sulfur. Only decoction or digestion is wanting to it.

Concerning the nature of Lead: Lead is an unclean and imperfect substance, procreated from impure, non-fixed, earthy, feculent Quicksilver, more or less white in its manifest and reddish in its occult properties, and from a similar partially combustible Sulfur. It is defective in purity, fixity, color, and in its comportment toward fire.

Concerning the nature of Copper: Copper is an unclean and imperfect substance, generated from an impure, non-fixed, terrestial Quicksilver, combustible, reddish but not bright, and from a Sulfur of a similar kind.

It is deficient in fixity, purity, and weight, and it has an excessive amount of impure color and incombustible earthiness.

Concerning the nature of Iron: Iron is an unclean and imperfect substance, generated from an impure Quicksilver, exceedingly fixed, earthy, and combustible, white and red, but not bright, and from a like Sulfur. It lacks fusibility, purity, and weight, and it has a remarkable amount of unclean fixed Sulfur and incombustible earthiness.

Every alchemist whatsoever ought to mark the things which have been said in the foregoing.

Chapter III. From what sources the material of the elixir may be elicited most conveniently.

The procreation of the metals, whether of the perfect or of the imperfect, is sufficiently definite in that which has been said. We now turn to the imperfect material which is to be perfected and chosen.

Since complex metals are procreated from Quicksilver and Sulfur, and are corrupt according to the impurity and uncleanness of these, as has been fully noted in the preceding chapters, and since no metallic thing can be evidenced which is not compounded from these or in some way originated from them, the inference is clear that no extraneous thing which does not take its origin from these two is capable and adequate to perfect them or to bring about any new transformations of them. It is a surprising thing therefore that a certain prudent man should found his intention on animal and vegetable substances which are remote, while mineral substances are sufficiently ready at hand. And it is not to be believed that any philosopher would propound this art in such remote terms, unless it be that he is speaking in a simile. Compound metals are made from the prime two, and nothing adheres to them, or transmutes them, unless it comes from them in the first place. So, of necessity, we must accept Quicksilver and Sulfur for the materials of our stone.

Neither Quicksilver itself alone nor Sulfur itself alone generates any metal, but the various metals and many mineral substances are procreated in various fashions from a commixture of both of them. Therefore our material must be chosen from a commixture of both.

But our final secret is most excellent and deeply occult—for it deals with the mineral thing from which our substance may be made most conveniently and most readily. And this is the thing we are bound to choose with care.

Suppose then that our material is chosen first from among vegetable substances, like grass, or trees, or anything else which grows up out of the earth. It is necessary in that case first to make Quicksilver and Sulfur from these by long decoction. But from that operation we are excused, for Nature provides us already with Quicksilver and Sulfur. And if we choose from among animal substances, like human blood, or hair of the head, or urine, or excrement, or hen's eggs, or anything else which proceeds from animals,

it is necessary to make Quicksilver and Sulfur from these by decoction; and from this we are excused as in the previous case. If we choose from mineral media, like the whole class of Magnesias, Marcasites, Tutias, Atraments or vitriols, alum, *Baurach* (borax), salts, and of many others, similarly it is necessary as in the earlier cases to make Quicksilver and Sulfur from them by decoction—and from this we are excused as in the other preceding cases. And if we choose any from among the seven spirits *per se*, as, for instance, Quicksilver alone, or Sulfur alone in kind, or Quicksilver and one of the two sulfurs, either *sulfur vivum*, or orpiment, or yellow Arsenic, or the red, alone or together, we will not by any means accomplish anything, for Nature does not get perfection without appropriate commixture of both. And neither can we. From these also, from Quicksilver and Sulfur in kind, we are excused as we were in the preceding instances. Finally, if we take the thing itself whatever it is that we must needs commix in its proper proportion, a proportion of which human genius is ignorant, and afterward cook to coagulation in a solid mass, then we are excused from taking the two substances in kind, namely the Quicksilver and Sulfur, because we are ignorant of the above-mentioned proportion and because we may find substances in which the proper materials occur proportioned, coagulated, and coadunated in the necessary manner.

Keep secret this secret.

Gold is a perfect and masculine substance without any superfluity or diminution. And if it is imperfect only as regards liquefaction, the material which would perfect it when mixed with it would be the *elixir ad rubeum*. Silver also is an almost perfect substance and is feminine, and, if it also is imperfect, the material which would almost perfect it by ordinary fusion alone would be the *elixir ad album*. But this is not the case and it cannot be, because gold and silver are perfected in their own nature. If their perfection should be commiscible with the imperfect, the imperfect would not be perfected by the perfect, but rather their perfection would be diminished by the imperfect and would be imperfected. But if the perfect should be in excess, two-fold, or four-fold, or an hundred-fold, or even more, sometimes the imperfect may be perfected.

Since Nature always works in a simple manner, perfection in gold and silver is simple, and inseparable, and incommiscible. They are not to be applied by art as a ferment for shortening the work of preparing the stone, and are reduced to their pristine state when the greatest amount of volatile exceeds the greatest of the fixed. And because gold is a perfect substance procreated from a red and bright Quicksilver and from a like Sulfur, we do not choose it for the material of the stone of the Red Elixir. The more so because it is already entirely perfected without ingenious cleansing, and is already so strongly digested and cooked by natural heat that we are scarcely able to work gold and silver in our artificial fire. Al-

though Nature may perfect a certain substance, she does not know, however, how to cleanse it intimately, or to perfect it and purify it, but she works upon it simply as she has it.

If therefore we choose gold or silver for the material of the stone, we shall have difficulty in finding a fire for acting on it. And even if we are not ignorant of a fire, we shall still not be able to attain its intimate cleansing and perfecting because of its exceeding strong compactness and natural composition. Wherefore we are excused from taking the first for the Red and the second for the White, since we may find a thing, or a certain substance, from as clean or cleaner Sulfur, and from Quicksilver, on which Nature has worked but little or not at all, which we are able, by our artificial fire and by the experience of our art, and by our own ingenious work continued beyond this, to bring to its congruous decoction, mundification, coloration, and fixation.

A material is therefore to be chosen in which there is a clean, pure, bright, white, and red Quicksilver, not brought in for completeness but commixed equally and proportionately in due fashion with a like Sulfur, and congealed in a solid mass, so that with our ingenuity and prudence and by means of our artificial fire we may be able to reach its intimate cleanliness and the purity of these ingredients, and so to bring about that they shall be a thousand thousand times stronger and more perfect after the completion of our work than the same simple substances decocted by natural heat. Be therefore prudent: for if you are subtle and ingenious in these chapters of mine in which I have demonstrated plainly and with manifest examination how the material of the stone ought to be understood, you will taste that delectable somewhat on which the whole intention of the Philosophers is settled.

Chapter IV. Concerning the method of procedure, both with a moderated and with a continued fire.

Unless your neck is of the stiffest and you are totally enveloped in a veil of ignorance and incipience, I believe that you have found, in what has already been said, the sure material of the philosophers of the blessed stone of the skilful, on which the operation of alchemy is to be directed when we attempt to perfect the imperfect and strive for perfection in many instances. And since Nature has provided us with the imperfect as well as with the perfect, it is necessary for us all the more to perfect by our work and artificial labor the material which has been noted in the sections devoted to that subject.

And if we are ignorant of the mode of procedure in the case, why do we not look how Nature commonly operates who really perfects the metals? And do we not see that in the mine, through the continued warmth which exists in mineral mountains, the grossness of water is cooked and inspissated to such an extent that in the course of time Quicksilver is made? And that,

by the same decoction and warmth, Sulfur is generated from the fatness of the earth? And that the compound metals are generated from these two according to their purity or impurity by the action of the same warmth upon them continued perseveringly? And that Nature joining sometimes the perfect and sometimes the imperfect, perfects by a single decoction or makes the metals?

O, immoderate madness! What drives you, I ask, to perfect these substances by strange, melancholy, and fantastic rules? A certain man once said, "Woe to you who wish to exceed Nature and even to perfect metals by a new regimen or by a process born of your own insensate capitosity. God gave to Nature a straight path, namely, continuous decoction, and you senselessly disdain to imitate her or are ignorant how to do it." Another, "Fire and *azot* suffice for your purpose." And another, "Heat perfects all things." And another, "Cook, cook, cook, and weary not of it." And another, "Let your fire be gentle and mild, maintained day after day with equal ardency; let it neither wax nor wane lest the greatest evil follow. And another, "Patiently and continuously." And another, "Grind it with seven turns." And another, "Know that by one thing, namely, by the stone, by one way, namely, by decoction, and in one vessel the whole magistery is terminated." And another, "It is cleansed by fire." And another, "This work is similar in many respects to the creation of man, for, as the child is nourished at first with lighter foods until the bones are formed, then with stronger ones, so this magistery requires a slow fire by which it is acted upon in the manner of a decoction. And always when we speak of a slow fire, we mean that the fire is to be augmented and made stronger gradually and in successive stages during the course of the work."

Chapter V. Concerning the quality of the vessel and of the furnace.

We have already determined the end of the work and the method of procedure. Now, concerning the vessel and the furnace, we may hear how they ought to be made and from what materials.

When nature decocts the metals with natural fire in the mine, she refuses to make the decoction without a vessel apt for the purpose. And if we propose to follow Nature in the matter of decoction, wherefore ought we to reject the vessel which she uses? First, then, we must look to see the kind of place in which the generation of the metals occurs. Manifestly this is seen to be in the places where minerals are found, for there is at the bottom of the mountain an equable and lasting heat whose nature it is always to ascend, and which in ascending always dries out everything and coagulates the denser and grosser waters in the bowels and veins of the earth or of the mountain into the Quicksilver which is hidden there. And if the mineral fatness of this place has been heated out of the earth in this manner and brought together in the veins of the earth, it runs through the mountain, and is Sulfur. And as may be seen in the above-mentioned

veins of this place, this Sulfur, generated from the fatness of the earth as has been said, also encounters the Quicksilver (as has also been written) in the veins of the earth, and procreates the denseness of mineral water. From this we ought to note the law in the case, that the mineral mountain is everywhere on the outside closed in upon itself and stony, for if its heat were able to escape no metal would ever be procreated.

If then we intend to imitate Nature, we must necessarily have a furnace of the same sort, after the fashion of the mountain, not in size, but of such sort as to provide a continuous heat so that the fire imposed upon it shall not find an exit when it ascends and so that the heat shall reverberate the tightly closed vessel which contains within itself the material of the stone. The vessel ought to be round with a short neck, of glass or of earthenware corresponding to the nature or compactness of glass, and its mouth ought to be closed with a suitable stopper and coated and sealed with bitumen. And as in the mines the heat does not touch directly the substance of the Sulfur and of the Quicksilver, because the earth of the mountain is everywhere between, so the fire ought not to touch directly the vessel which contains the above-mentioned materials. But this vessel must be placed within another vessel similarly closed, so that a temperate heat may better and more aptly reach the material above and below and from whatever side it may be. Whence Aristotle says in the *Lumen Luminum* that Mercury is to be cooked in a triple vessel, which vessel ought to be of the hardest glass, or, what is better, of earthenware having the nature of glass.

Chapter VI. Concerning accidental and essential colors which appear in the work.

You understand the exquisite material of the stone and the certain method of procedure, by which method, and by what regimen the stone is frequently transmuted into various colors during the decoction. Hence a certain one says, "So many colors, so many names." According to the various colors appearing in the work, its names are varied among the Philosophers. Hence the first operation on our stone is called putrefaction, and it makes our stone black. Hence a certain one says, "When you see this black, you may know that in this blackness whiteness is hidden, and then it is necessary to extract it from this most subtle blackness of it." Indeed, after putrefaction it reddens, but not with true redness, for which reason a certain one says, "Often it reddens, and often it yellows, and often it liquifies, and often it coagulates before true whiteness." And it also dissolves itself, coagulates itself, putrefies itself, colors itself, mortifies itself, vivifies itself, blackens itself, whitens itself, and decorates itself blushingly with whiteness. It also turns green. Hence another one says, "Cook until it appears to thee to be born green, and this is the soul of it." And another, "Know that in greenness this soul is dominant." The color of the peacock also appears before whiteness, for which reason a certain one speaks thus,

"Know that all colors which are in the world or which may be imagined appear before whiteness, and thereafter true whiteness follows." Hence a certain one says, "Its utility is to be expected when it is fully cooked pure until it glows like the eyes of a fish, and then the stone is congealed in rotundity." Another says further, "When you shall find supereminent whiteness in the vessel, be sure that in this whiteness redness is hidden. It then behooves thee to take it out." Nevertheless, cook until everything becomes red. For between true whiteness and true redness there is a certain color similar to ashes, concerning which it is said, "After the whiteness you will not be able to go astray, for you will attain the ash by augmenting the fire." Concerning which another says, "Do not despise the ash for God will give it back to thee liquified." And then finally the king is crowned with the red diamond, BY THE WILL OF GOD.

Chapter VII. Concerning the manner of projecting the medicine on any imperfect substance whatsoever.

I have achieved the end of the perfected thing which was promised, namely, of the great magistery of making the most excellent red and white *elixirs*. Finally, we must treat of the method of projection, which is the fulfilment of the work and the desired and expected pleasure.

Any red elixir produces yellow endlessly and transmutes all metals into purest gold. And the white elixir truly whitens to infinity and converts all metals whatsoever to perfect whiteness. But it must be known that one metal is more distant from perfection than another, and one nearer than another and more similar. And although any metal is reduced to perfection by the elixir, the near ones are reduced more easily, sooner, and more perfectly than those which are more remote. And when we find a metal near and similar to perfection, we are excused through it from many which are remote. Which metals are indeed remote, and which near, and which are nearer and more similar to perfection, you will find, if you are wise and ingenious, sufficiently plainly and veraciously determined in my little chapters. And without doubt he who is ingeniously intent on this my *Speculum* to the end that his industry may know how to find the true material, he will know very well on what body the medicine for perfection ought to be projected.

Indeed the precursors of this art, who discovered it through their philosophy, point sufficiently clearly with their finger to the straight and open way when they say, "Nature contains Nature; Nature exceeds Nature; and Nature opposing her own nature is gladdened and is transmuted into alien Natures." And another, "Every similar applauds its similar, for similitude is called the cause of friendship," concerning which many philosophers have left a notable secret. Know that a soul enters its own body directly which does not by any means join with a foreign body. And another, "Indeed the soul enters directly into its own body, but you will labor

in vain if you believe to join it with an alien body." Surely this affinity is especially lucid.

Since corporeal things in the procedure are made incorporeal, and conversely, incorporeal are made corporeal, and since in the completion of it the whole substance is made spiritually fixed, and since this evidently spiritual elixir, whether white or red, is greatly prepared and deduced, it is no wonder that it is incommiscible with the barely melted substance on which it is projected.

It is also a mistake to project upon a thousand thousand and more and to penetrate into it at once and transmute it. On this point I now reveal to you a great and hidden secret. One part ought to be mixed with a thousand parts of an allied substance, and the whole shut up tightly in a suitable vessel and placed in a furnace of fixation, with a slow fire at first which is increased continually for three days until the materials are inseparably joined. And this is the work of three days. Then, again and finally, any convenient portion of this ought to be projected, always one part of this for another thousand parts of an allied substance. And this is the work of one day, or of one hour, or of a moment. For which, our God ever marvelous is to be praised in eternity.

BIBLIOGRAPHICAL NOTE

The present translation has been made from the Latin text which is printed in the book, *Alchemiae Gebri Arabis philosophi solertissimi, Libri, cum Reliquis*, etc., Berne, **1545,** pp. 208–19. We have also used that of the *Theatrum Chemicum*, Ursellis, 1602, Vol. **2,** pp. 433–42, and have been aided by the French translation, *Le Miroir D'Alquimie* (wrongly ascribed to *Iean de Mehun, Philosophe Tres-Excellent*), Paris, **1613,** and the German translation, *Roger Bacons Alchymeyspiegel oder kurzgefasste Abhandlung der Alchemey*, which is printed in the *Neue Alchymistische Bibliothek für den Nuturkindiger unsers Jahrhunderts ausgesucht und herausgegeben von S.*, Frankfurt and Leipzig, **1774,** Vol. **2,** pp. 167–92. The editor of the German translation, Schröder, points out the verbal similarity between the seventh chapter of Roger Bacon's *Mirror of Alchemy* and the eighth chapter of Avicenna's *Little Book of the Mineral Stone* (*Des Avicennas kleines Büchelchen vom mineralischen Steine; nebst Anfange der Erläuterung desselben vom fysischen Steine*), but does not tell the sources from which his translations were made.

Ferguson's *Bibliotheca Chemica*, Glasgow, **1906,** lists a number of editions, among them an English translation, London, **1597,** which we have not seen.

Sea Salt Causes Red Stain on Hides. Large areas of brick-red discoloration which sometimes occur on hides have been traced to the use of sea salt for curing the hides. The color is due to immense numbers of red bacteria which are similar to those which have been found fairly often on salted fish. The bacteria can stand remarkably high concentrations of salt.

Miss Madge E. Robertson, of the laboratories of the British Leather Manufacturers' Research Association, London, has found that the ordinary bacteria of dust and dirt cannot produce the red stain, but the color is readily produced by the salt-loving organisms which are found in sea salt.—*Science Service*

THE STORY OF NICKEL. PART II. NICKEL COMES OF AGE

WILLIAM H. BALDWIN,* INTERNATIONAL NICKEL COMPANY, INC., NEW YORK CITY

Nickel's post-war ascendancy in industry, creating in 1929 a demand far in excess of the war-time consumption, has been due to the interplay of three groups of forces. One group, naturally, is composed of nickel's main properties—its rustlessness, its resistance to corrosion, its ability to decolorize metals with which it is alloyed, its magnetic qualities and its power to impart to iron, steel, and copper greater fabricability and improved performance. The second group of forces includes the research activities both of the nickel industry itself in finding and developing new uses for the metal, and of other industries in seeking new alloys to improve their processes or products. Supplementing and stimulating these various forces have been all those forces which have made for the healthy discontent of industry with pre-war standards and practices.

Nickel has permeated the automotive industry and has spread to the construction of the great steam locomotives. It has increased the magnetic qualities of iron, thus participating in the miracles of radio and the "talkies." It is the basis of the present vogue for white metals, including the stainless steels. Used for its decolorizing properties in the manufacture of white gold, it even adorns the modern bride whose groom cannot afford a platinum wedding ring.

Monel metal, the distinctive natural alloy of the Canadian nickel industry, is described. Its uses in industrial processes and for food-handling equipment are recounted, and its great service to the housewife in modernizing the kitchen sink is told.

. . . . . .

Nickel's Post-War Ascendancy

When the World War suddenly broke out in August, 1914, the nickel refineries in this country promptly shut down, so little was the importance of this metal understood. They remained closed until the following October when the world began to realize that stronger and tougher steels were a vital element of victory.

Then the production of this metal to meet the insatiable demands of the Allies began to build up until, four years later, ingots as they came glowing from the refinery at Bayonne were doused with cold water and rushed to the steamers for shipment to the gun and ammunition factories of France and England. So great was the value put on nickel that no more than 500 tons were allowed on any one vessel traversing the submarine zone, and the day that the United States entered the war the Army assigned a company of soldiers to the Bayonne refinery. This guard was maintained until the armistice.

Another four years—the war is ended and the temper of the world is toward progressive reductions in the great naval armaments. Nickel is

* Public Relations Counsel to The International Nickel Company, Inc. The author reserves all rights in this article.

again a drug upon the market. Practically 90 per cent of the world's consumption had been in the manufacture of armaments and the munitions of war, and this market was wiped out to all intents and purposes.

Then began the slow and persistent work of research, experimentation, and merchandising, which has given nickel as heroic a stature in the many fields of industry as it ever had on the battlefields. Indeed, in 1929, more of the metal was used than had been consumed at the peak of wartime consumption. Nickel came of age in the laboratories of the great electrical companies, on the proving grounds of the automobile makers, in the test flights of airplane engines, and in countless other places where the search for better materials and better performance is unabated.

Quite naturally the nickel industry itself has been at the forefront of this research, for its very life has been dependent upon finding and developing new markets. At the same time this task has been considerably lightened by the healthy discontent with old standards and practices, with which industry as a whole emerged from the World War.

Behind this discontent has been a fascinating interplay of factors, and thoughtful observers feel that the contribution of the war was in accelerating rather than in actually creating the development. They find the roots of the present situation in the pre-war combination of physics and chemistry and in metallography, the child of that union. Metallurgy had developed as an intensive study of the chemistry of metals; then came metallography with a physico-chemical background to delve into the structure of metals and to study the changes which could be effected in the grains of metals by the introduction of various elements in combination and by variations in heat treatment and in quenching. At the same time a psychological factor became evident. Our colleges and technological schools were turning out more and more young men who were scientifically trained and who were eager for jobs. These boys soon realized that, so long as industrial processes rocked along under a rule-of-thumb policy, they would have a hard time getting placed. Thus they found that they must use their imagination and create needs within industry for their special knowledge which previously had been considered as good only for theorizing in the classroom and the college laboratory.

Prior to the war the great electrical companies had established research as a practical function of their activity, and certain of the automobile makers had hired metallurgists. The steel business is old and tough, and these young newcomers were greeted with contempt by the veteran steel men who had been accustomed to getting specifications modified to suit their production methods rather than to working out a production that would meet the specifications. These were the days of the horseless carriage, when something more than the horse was frequently missing. Rear axles were brittle, gears stripped, valves stuck. The driver's head

was as often under the hood or under the chassis as it was above the wheel. Much of the trouble was, of course, due to the inexperience of the designing departments in writing proper specifications; but even more trouble was due to the stubbornness of the production departments in failing to work with the metallurgists in meeting the specifications given.

Then came the war and many an industrial plant took orders for military supplies. Government inspectors came into the plants and proceeded to reject products right and left as being below specification. The shop foremen and the foundrymen had to turn to the metallurgists for help, and the union between industry and science was thereupon effected. At the same time the government drafted not only young graduates but also professors and research men from the scientific schools for work in planning boards and as officers of ordnance and in the service of supplies. With the close of the war many of these men turned to industry for their further careers. Thus the stage was set for a modernized attitude toward production and for an enlightened interest in the potentialities of alloys. The old complacency with three types of special steels—manganese for wear resistance, nickel for toughness, and chrome-nickel where both strength and toughness were required—was shelled at Liége and had been evacuated long before St. Mihiel.

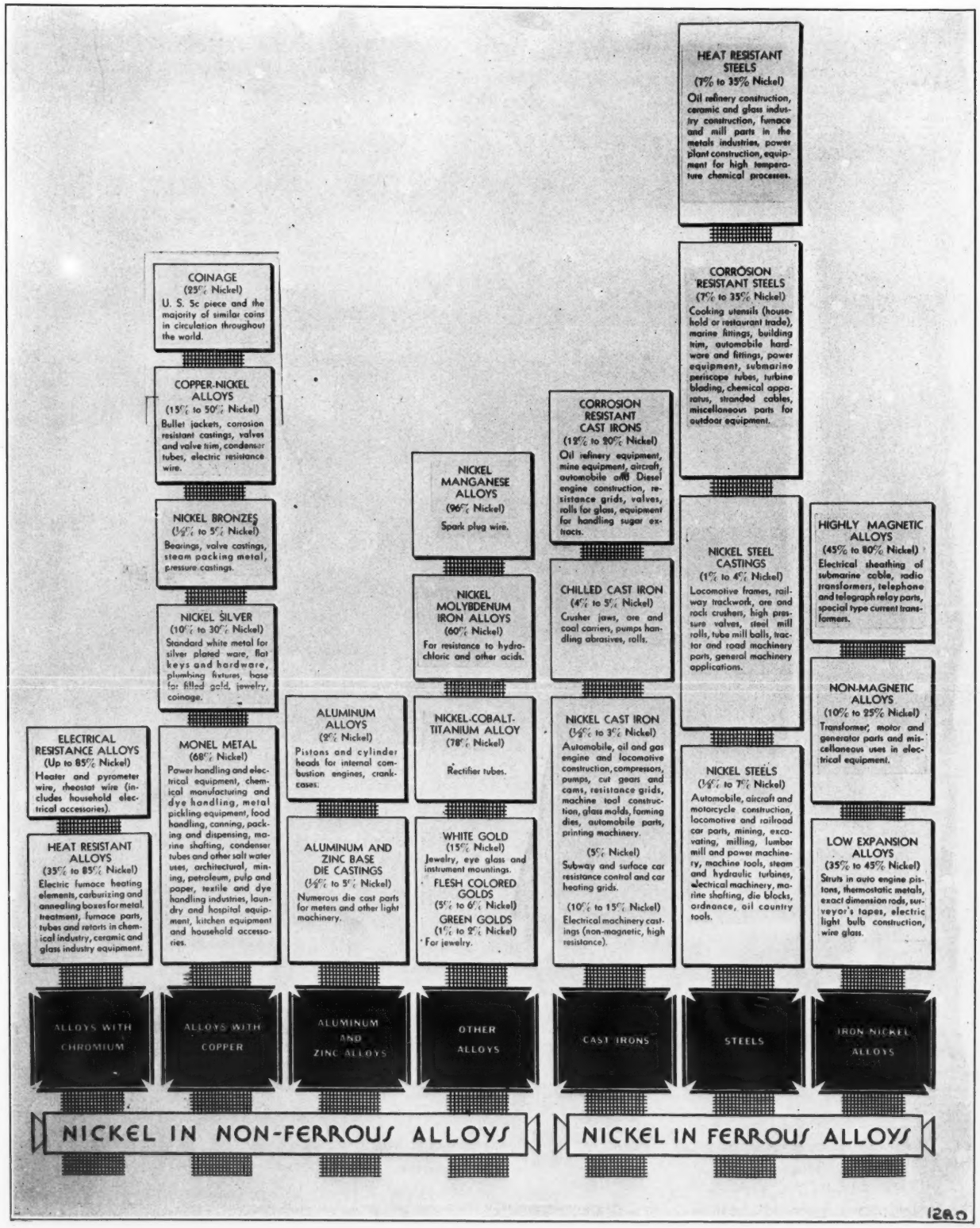
Thus the nickel industry saw the World War write *finis* to its one great market, and at the same time prepare the broad field of industry for cultivation as the new market for nickel.

Nickel in the Automotive and Locomotive Industries

What the automotive industry has meant to nickel in this post-war recovery is indicated by this figure: in 1930, a year of greatly restricted output of cars, the automobile makers took 10,900,000 pounds of nickel, or nearly one-third of the total consumption in the United States and Canada. The previous year the poundage had reached the enormous sum of 16,500,000 as compared with 3,400,000 pounds used in this industry in 1921.

But nickel did not inherit this market free and clear of all strings; it had to win the business in its own right. There were two important factors working against the metal. The first was the appreciable amount of bad nickel steels produced under the stress of war. The demand had been so great that steel mills lacking both experience and equipment had turned out stuff that had caused all sorts of trouble. The second factor was symbolized in the crankshafts for the Liberty motors. These important parts were made of such a high alloy of nickel and chrome that they were almost impossible to machine with the tools then available. The result was that fabricating plants were as anxious to get rid of nickel steels as the soldiers were to doff their uniforms.

To meet this situation metallurgists who had had practical experience in


HEAT RESISTANT STEELS
(7% to 35% Nickel)
Oil refinery construction, ceramic and glass industry construction, furnace and mill parts in the metals industries, power plant construction, equipment for high temperature chemical processes.
CORROSION RESISTANT STEELS
(7% to 35% Nickel)
Cooking utensils (household or restaurant trade), marine fittings, building trim, automobile hardware and fittings, power equipment, submarine periscope tubes, turbine blading, chemical apparatus, stranded cables, miscellaneous parts for outdoor equipment.
COINAGE
(25% Nickel)
U. S. 5c piece and the majority of similar coins in circulation throughout the world.
COPPER-NICKEL ALLOYS
(15% to 50% Nickel)
Bullet jackets, corrosion resistant castings, valves and valve trim, condenser tubes, electric resistance wire.
NICKEL BRONZES
(½% to 5% Nickel)
Bearings, valve castings, steam packing metal, pressure castings.
NICKEL SILVER
(10% to 30% Nickel)
Standard white metal for silver plated ware, flat keys and hardware, plumbing fixtures, base for filled gold, jewelry, coinage.
NICKEL MANGANESE ALLOYS
(96% Nickel)
Spark plug wire.
NICKEL MOLYBDENUM IRON ALLOYS
(60% Nickel)
For resistance to hydrochloric and other acids.
CORROSION RESISTANT CAST IRONS
(12% to 20% Nickel)
Oil refinery equipment, mine equipment, aircraft, automobile and Diesel engine construction, resistance grids, valves, rolls for glass, equipment for handling sugar extracts.
CHILLED CAST IRON
(4% to 5% Nickel)
Crusher jaws, ore and coal carriers, pumps handling abrasives, rolls.
NICKEL STEEL CASTINGS
(1% to 4% Nickel)
Locomotive frames, railway trackwork, ore and rock crushers, high pressure valves, steel mill rolls, tube mill balls, tractor and road machinery parts, general machinery applications.
HIGHLY MAGNETIC ALLOYS
(45% to 80% Nickel)
Electrical sheathing of submarine cable, radio transformers, telephone and telegraph relay parts, special type current transformers.
NON-MAGNETIC ALLOYS
(10% to 25% Nickel)
Transformer, motor and generator parts and miscellaneous uses in electrical equipment.
ELECTRICAL RESISTANCE ALLOYS
(Up to 85% Nickel)
Heater and pyrometer wire, rheostat wire (includes household electrical accessories).
HEAT RESISTANT ALLOYS
(35% to 85% Nickel)
Electric furnace heating elements, carburizing and annealing boxes for metal treatment, furnace parts, tubes and retorts in chemical industry, ceramic and glass industry equipment.
MONEL METAL
(68% Nickel)
Power handling and electrical equipment, chemical manufacturing and dye handling, metal pickling equipment, food handling, canning, packing and dispensing, marine shafting, condenser tubes and other salt water uses, architectural, mining, petroleum, pulp and paper, textile and dye handling industries, laundry and hospital equipment, kitchen equipment and household accessories.
ALUMINUM ALLOYS
(2% Nickel)
Pistons and cylinder heads for internal combustion engines, crankcases.
ALUMINUM AND ZINC BASE DIE CASTINGS
(½% to 5% Nickel)
Numerous die cast parts for meters and other light machinery.
NICKEL-COBALT-TITANIUM ALLOY
(78% Nickel)
Rectifier tubes.
WHITE GOLD
(15% Nickel)
Jewelry, eye glass and instrument mountings.
FLESH COLORED GOLDS
(5% to 6% Nickel)
GREEN GOLDS
(1% to 2% Nickel)
For jewelry.
NICKEL CAST IRON
(½% to 3% Nickel)
Automobile, oil and gas engine and locomotive construction, compressors, pumps, cut gears and cams, resistance grids, machine tool construction, glass molds, forming dies, automobile parts, printing machinery.
(5% Nickel)
Subway and surface car resistance control and car heating grids.
(10% to 15% Nickel)
Electrical machinery castings (non-magnetic, high resistance).
NICKEL STEELS
(½% to 7% Nickel)
Automobile, aircraft and motorcycle construction, locomotive and railroad car parts, mining, excavating, milling, lumber mill and power machinery, machine tools, steam and hydraulic turbines, electrical machinery, marine shafting, die blocks, ordnance, oil country tools.
LOW EXPANSION ALLOYS
(35% to 45% Nickel)
Struts in auto engine pistons, thermostatic metals, exact dimension rods, surveyor's tapes, electric light bulb construction, wire glass.
ALLOYS WITH CHROMIUM
ALLOYS WITH COPPER
ALUMINUM AND ZINC ALLOYS
OTHER ALLOYS
CAST IRONS
STEELS
IRON NICKEL ALLOYS
NICKEL IN NON-FERROUS ALLOYS
NICKEL IN FERROUS ALLOYS
1280

the automotive field were set to work developing new nickel alloys and the proper technic for working them. These men became a clearing house for information and a staff of trouble menders. They carried the gospel of nickel directly to the foundry bosses and the shop foremen, and put their scientific knowledge on the shirt-sleeve basis of helping to work out production problems on the job.

Naturally, the tremendous growth in the number of cars built has contributed directly to the expanding market for nickel in this field, but another factor has been the increase in the number of parts containing nickel. The English racing car "Blue Bird," which recently established a world speed record of 245 miles an hour, is of course the most complete assembly of alloy steels; but the average passenger car is not very far behind in this respect. Take, for example, the matter of trim. It is either stainless steel, which is an alloy containing at least eight per cent nickel, or it is nickel plated, or it is chrome plated. In this last case the chrome is a light plate over a heavier nickel plate!

But nickel's contribution to modern car design is much greater and more important than the decorative trim. Axles, pinions, gears, crankshafts, clutch plates, steering knuckles, and other key parts are now of alloys especially developed to meet their individual performance requirements, and practically all of these alloys have a nickel content.

One of the newer and most promising developments has been in the field of nickel-cast-iron alloys for cylinder blocks, manifolds, and brake drums. It has been found that a small percentage of nickel—in some instances combined with other alloying elements—does things to both the machinability and the performance of cast iron, which have dramatically saved that ancient material from the discard in modern machine design. Already one hundred models of trucks and buses have standardized on chrome-nickel cylinder blocks, and there has been universal adoption of nickel-cast-iron brake drums for these heavy jobs. The larger and better passenger cars are beginning to follow this trend.

What nickel has done for itself in the automotive field it is now proceeding to repeat in the even heavier units of locomotive construction. The development of nickel cast iron has increased the tensile strength from a low point of 18,000 pounds for common cast iron to 40,000 pounds for this new material and has thus made possible the retention of cast iron cylinders on even the most powerful engines. At the same time this introduction of nickel into the cast iron has eliminated the need for liners in the cylinders until they have had many thousand miles of useful service. Likewise, nickel-cast-iron grate bars are becoming standard; and in the field of nickel-steel castings the heavy locomotive frames are becoming important, because nickel steel stands up under the terrific stresses imposed on these frames when engines take curves at high speed.

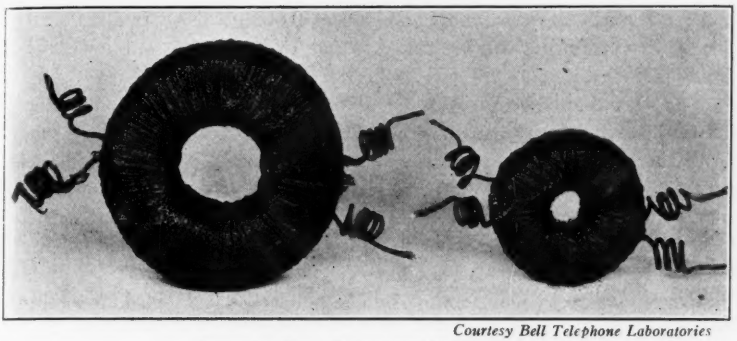
A year ago the Timken Roller Bearing Company decided to build a steam locomotive as a demonstration of the efficiency of roller bearings in railroad transportation. A group of the leading designers were asked to make it the most perfect engine ever built as to both design and materials. This locomotive, which is now being lent to various railroads for test under actual traffic conditions, was built to combine the minimum weight with the maximum strength and efficiency, and it is therefore significant that more than 100,000 pounds of nickel alloy steel have been used. A 2% low-carbon nickel steel was selected for the boiler plate and firebox sheet; $2^1/_2$ to 3% nickel steel is used for main rods, side rods, eccentric rods, and crank pins, a 1% nickel steel for bearing housings and a nickel-vanadium steel for frames, return cranks, crossheads, and crosshead shoes. Likewise, nickel cast iron has been employed for valve and cylinder bushings, superheater header, throttle valves, main rod bushings, and middle connection side rod bushings.

Nickel Alloys in the Electrical Field

Long before nickel steels were roaring down Daytona Beach at 245 miles per hour in the Blue Bird or hauling great trains in the Timken locomotive, a certain nickel-iron alloy was participating in even more spectacular developments of modern life.

The English nightingale, whose notes are carried across the Atlantic to listeners throughout the United States; the business man who puts in a call from New York to Chicago as part of the day's routine; the diplomat who files an important cable message to his home government; the "talkie fan" who will listen tonight to her favorite actor who actually spoke months before in far-off Hollywood—all these have as their silent partner a magic metal called *permalloy* which has revolutionized science's conception of magnetism and its potentialities in the electrical transmission and reproduction of sound.

In the development of this metal is reflected a field of scientific research in which the nickel industry is proving the beneficiary of another industry's activities. Permalloy is the result of years of study in the Bell Telephone Laboratories where much of the preliminary work would have seemed abstruse and far afield even to most technical men. For example, it included the development of a comprehension of *magneto-striction*, the name which has been given to the phenomenon of growth in iron when it is magnetized. That growth, due to the rearrangement of the atoms in a bar of iron that is being magnetized, is imperceptible to anything but the most delicate instruments; but the scientists have measured it and they know it reflects the expenditure of energy which, from their point of view, is waste. These scientists have also found that a bar of nickel contracts when it is magnetized. Thus they combine both nickel and iron in an alloy which neither expands nor contracts and which thus gives them an ideal magnetic material. The



Courtesy Bell Telephone Laboratories

REDUCES SIZE, INCREASES EFFICIENCY

The nickel-iron alloy known as permalloy is rapidly being introduced into the telephone plant, in compressed powdered form, in loading coils, because its magnetic properties make possible reductions in the size and weight of the apparatus. The photo shows the comparative sizes of equivalent loading coils using iron (left) and permalloy (right). Some 1,785,000 loading coils were manufactured for telephone use in 1929 alone.

experiments incidental to this research developed the importance of heat treatment in the production of the alloy, and they also established the useful range of nickel content as being from 30 to 80%.

Dr. H. D. Arnold and Dr. Gustaf W. Elmen, who took the leadership in developing this series of heat-treated, nickel-iron alloys of high nickel content, gave them the name permalloy because of the permeability to magnetism. Carrying their studies further, they worked out another range of alloys in which the nickel content runs below 30% and to which cobalt has been added. This series they have named *permivar* because the permeability is directly proportional to the strength of the magnetizing field and, thus, invariable. Both types of alloys have already found useful work in the field of communications and consequently have created a market of high potentiality for nickel.

At the same time Dr. T. D. Yensen, who had studied the magnetic properties of nickel-iron alloys at an even earlier date, resumed his work in this field. Realizing the importance of the heat treatment, he went a step further and experimented with the atmospheric conditions under which the heat was applied. He adopted the theory that oxygen within the alloy was a serious deterrent to the ideal functioning of the material, explaining that impurities amounting to only a few hundredths of one per cent produce differences in magnetic properties amounting to several hundred per cent. He has therefore eliminated all but the irreducible traces of this gas by subjecting his alloy to many hours of high temperatures in pure hydrogen. The product, which he has named *hipernik* is a nickel-iron alloy of 50% nickel content, and it is being developed by the Westinghouse Laboratories

as a particularly effective material for the 10,000,000 transformers used in this country in the distribution of electricity for light, heat, and power in our homes and factories.

In another branch of the electrical field nickel has also established its usefulness. That is in the production of household electrical accessories and industrial heating devices where electrical resistance alloys containing up to 85% nickel are standard for heater and pyrometer wire and for rheostat wire. When one considers both the variety of these household accessories—irons, toasters, stoves, heaters, coffee pots, etc.—and the extent to which the average American home is becoming electrified, this market for the consumption of nickel becomes one of great potentiality. And here again independent research by the manufacturers of electrical appliances has been an invaluable ally of the nickel industry in its own efforts to find and develop new uses for the metal.

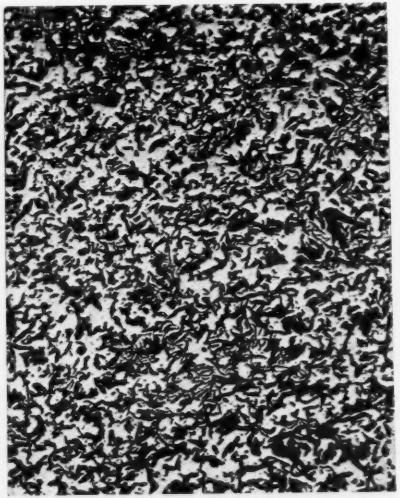
Monel Metal

In quite a different category is a non-ferrous alloy developed by The International Nickel Company which, as The International Nickel Company of Canada, Limited, has brought the various American and British enterprises into a single organization producing approximately 90% of the world's output of nickel.

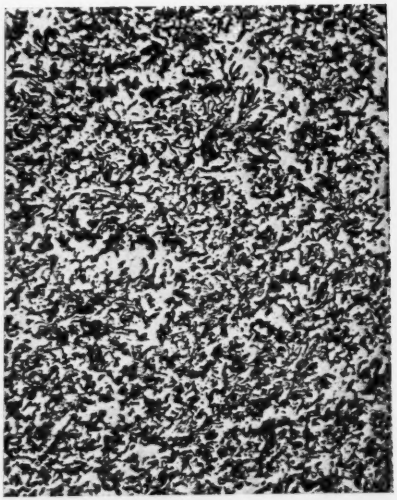
This alloy frankly owed its birth to no exercise of patient research but to a happy flight of imagination—a combination of shrewdness, sentiment, and hunch. Twenty-five years ago the rich ores of the Creighton mine in the Sudbury district were the main source of supply for the old International Nickel Company of which the late Ambrose Monell was president. These ores ran just about twice as much nickel content as copper. It will be remembered that the separation of nickel and copper was a hard nut for the metallurgists of a generation ago to crack. Colonel Monell had the bright idea that a natural alloy would result from refining the copper and nickel together without separating them. The idea was put to a test and it worked. The product was named Monel metal; and now, after years of intensive research and of improvements in production methods, it is described as "a technically controlled nickel-copper alloy of high nickel content—Monel metal is mined, smelted, refined, rolled, and marketed solely by International Nickel."

The particular merits of this alloy are its silvery brightness, its rustlessness, and its resistance to corrosion. The steel industry found it well adapted to use in the pickling tanks in which many steel products must be treated. The salt industry discovered that screens of Monel metal wire would withstand the attacks of wet salt. The power industry learned that valves, pump rods, and other vital parts of the machinery used in handling steam, would have a much longer life if made of Monel metal.

No Nickel



0.73% Nickel



2.12% Nickel

METALLOGRAPHY KNOWS, PHOTOMICROGRAPHY SHOWS
(Magnification ×30)

Metallography stresses the importance of grain structure in metals. Developments in photography bring out for the layman what small percentages of nickel will accomplish in increasing the strength of gray cast iron by breaking up the large graphite flakes which produce planes of weakness.

Then came its introduction into the field of food-handling equipment. Because it is a solid metal that looks well, that does not rust, that resists staining by food acids, and that is easy to keep clean and bright, Monel metal has become standard for soda fountains, for lunch counters, and for the kitchen and service pantry installations in the leading hotels, restaurants, and hospitals throughout the country. In the meantime commercial laundries and the manufacturers of electric washing machines turned to this alloy for protection against rust and stains.

The ramifications of Monel metal into modern life also include such examples as these: a laundry in Atlanta, Georgia, uses a thin strip of the alloy to keep the rear buttonhole from becoming welded to the neckband of men's shirts during the process of starching and ironing; a furniture maker in Grand Rapids, Michigan, uses only Monel metal tacks in his upholstery division because his men insist on holding tacks in their mouths, and common tacks so treated would rust and thus stain the upholstery; a company has been formed in New York to make huge thumb tacks of Monel metal. These are driven into the pavement of streets and highways to form traffic markers which will remain permanently bright and visible. Such markers have already been installed at important traffic intersections in the leading cities of the United States, Japan, and Europe.

Another use is still in its infancy, but it is of direct interest to every housekeeper and of real significance in the development of markets for nickel. Upwards of 1,000,000 kitchens and service pantry sinks are bought in the United States each year either for new homes or for modernizing old ones; yet, until the last few months, there had not been a major improvement in sink design since the days of Rutherford B. Hayes, when cast-iron sinks with enamel surfaces were introduced.

The kitchen sink, to be brutally direct, has been branded as a laggard in the brilliant march of American progress. Like the weather, it has been the subject of discussion but not of action. Now, backed by extensive experience with hotel and hospital installations and fortified with the knowledge that some 10,000 custom-built sinks of Monel metal have gone into the finest American homes during each of the past few years, The International Nickel Company has moved to expunge this blot and to dress up the Cinderella of the home so that she may take her place with her haughty sisters, the electric ice-box and the washing machine.

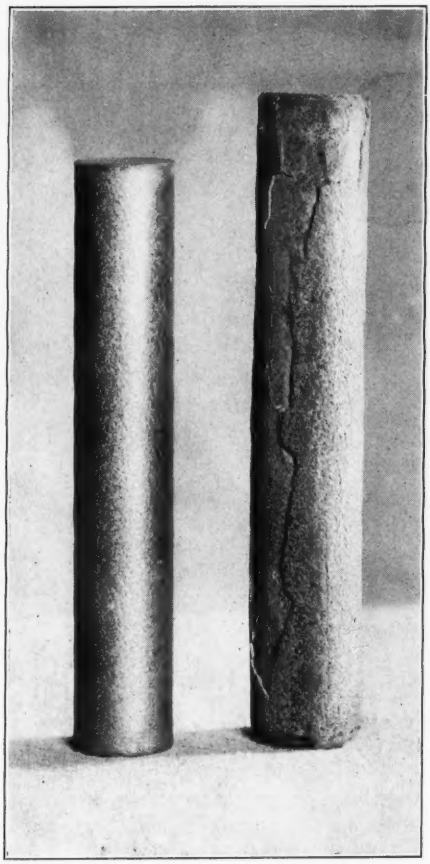
The first move was made two years ago when a national sink design contest was held and the winning designs were displayed at the Art Center in New York. The next step was to get a leading professional designer to take in hand these ideas and the suggestions of experts in home economics, and to evolve from this material a series of practical models. Then a factory which is experienced in stamping out automobile bodies from sheet metal was given the assignment of stamping out kitchen sinks from Monel metal sheets.

BEAUTY AND THE SINK

Monel metal and the Machine Age have combined to give the housewife new standards in sink design. The alloy offers a solid, silvery material which can be so molded as to provide nearly a third more working space. Mass production methods permit its being stamped out at relatively low cost. Incidentally, American homes take 1,000,000 new sinks a year.

Three models were exhibited at the Architectural Show in New York last spring and were enthusiastically received. They are handsome not only in the texture of their silvery brightness but also in their proportions. They are intensely practical in being of a solid material which cannot chip or crack and which is easily kept clean with any of the common household abrasives. They have the further utilitarian value of providing a third more working area than the old-fashioned sinks of the same outside dimensions; and, as drainboard and bowl are a continuous piece of metal, they offer no cracks or crevices as depositaries for dirt.

It is not to be expected that these new sinks are going to capture the market over night, but it is reasonable to suppose that they will become an important factor on the basis of their obvious superiority over the older types. Taking forty pounds as a conservative average of the nickel content in the various sizes, the winning of even a small fraction of the million sinks sold each year will create a new and important market for nickel in the home.



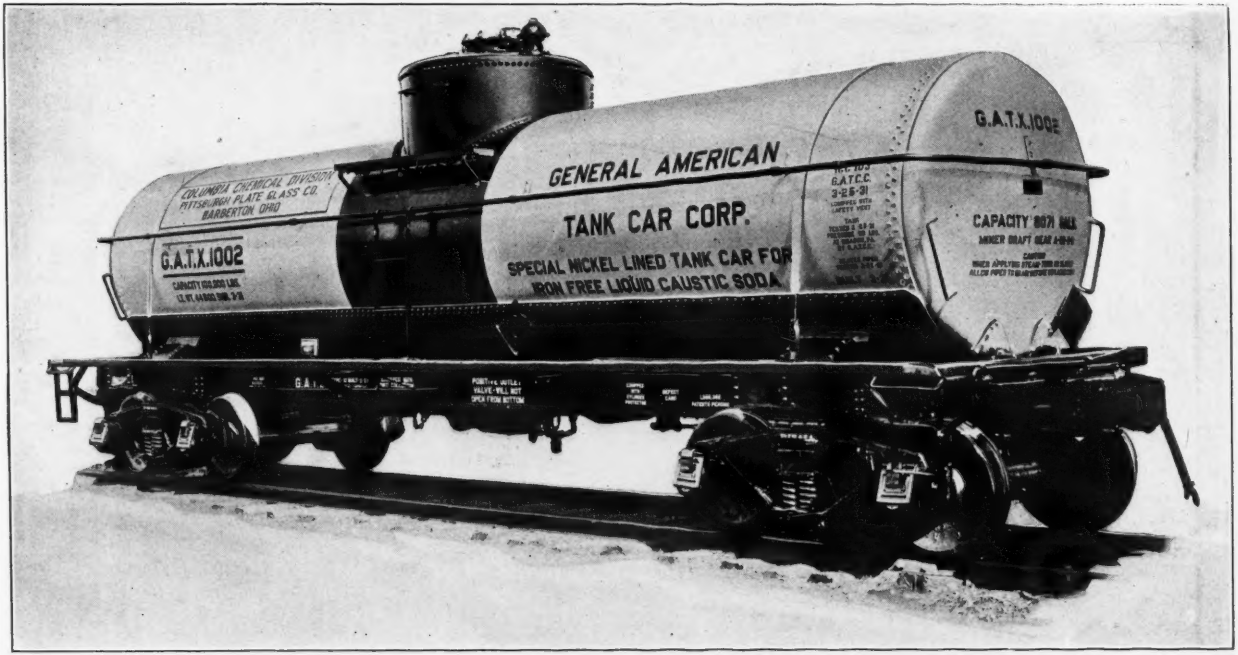
CAST IRON GROWS; NI-RESIST DOESN'T

This photograph shows graphically the relative growth and warpage of plain cast iron (right) and Ni-Resist after repeated heating and cooling. Large castings of common cast iron have been known to grow two inches in a year. Ni-Resist is a nickel-copper-chromium cast iron in which such growth is arrested. Other features of the alloy are its resistance to mild heat and to corrosion.

White Metals

Nickel has taken the leadership in still another field, that of white metals which are enjoying a growing vogue as decorative material. The most spectacular examples are, of course, the Chrysler Tower and the Empire State Building, the giant skyscrapers which are sheathed with tons of stainless steels. Just as dramatic in its way is the change in fashion from yellow gold wedding rings to those of white precious metals—either platinum, or white gold which depends upon a small content of nickel for its color. Likewise, the trim of our automobiles, the decorative effects of our newest banking institutions, the interiors of hotel lobbies and of small shops and great mercantile establishments, as well as their exteriors, are making us all increasingly conscious of the trend to bright metals.

Although nickel silver and nickel plating had long had certain established uses, it was the promotional work in marketing Monel metal that gave this present trend a real impetus. Recent applications include the famous T. Eaton Store in Toronto, which has employed 250,000 pounds of this alloy in its show windows and cases and in the interior decoration; and it has also been used extensively for decorative effect in the Union Trust Building in Detroit, the Wall & Hanover Building in New York City, the Board of Trade Building in Chicago, the William Len Hotel in Mem-



NICKEL-CLAD STEEL SHOWS ITS USEFULNESS

This tank car is used to transport caustic soda in bulk with an indicated saving of $1,000,000 a year to the rayon industry. It has been made possible by a new method of bonding and rolling heavy sheets of steel and nickel. Nickel-clad plates give the corrosion resistance of pure nickel at a considerable saving in cost.

Underwood & Underwood

NICKEL BRONZE FOR BEAUTY

"The Spirit of Achievement," the heroic figure modeled by Nina Saemundsson for the main portal of the new Waldorf-Astoria Hotel. Made in a single casting of 8 per cent nickel bronze, the statue is eight feet one inch in height and weighs 420 pounds.

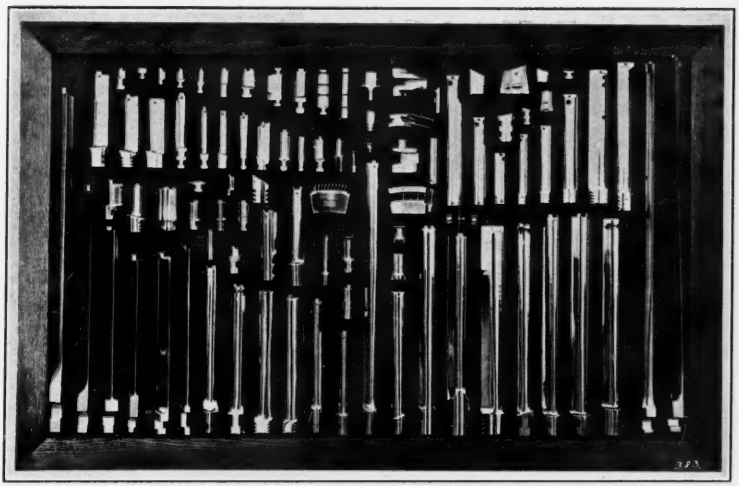
phis and in various private residences.

But the field of white metals spreads beyond Monel metal, the stainless steels, and white gold. Nickel silver, for example, has become standard for good plumbing fixtures (all government buildings that cost more than $1,000,000 specify nickel-silver fixtures), and for hardware, silver-plated ware, flat keys, and sundry other purposes. In addition, there are the silver bronzes which compete with Monel metal and the stainless steels for decorative trim in banks and monumental buildings.

From all of these applications the nickel industry derives benefit. Take the matter of automobile trim, as an example. If it is Monel metal or nickel-plated, the benefit is obvious; if it is one of the stainless steels, that steel will contain at least eight per cent; if it is chromium-plated, the chromium has been plated on a base of heavy nickel plate!

In short, the remarkable ability of nickel to decolorize other metals with which it is alloyed (the American five-cent piece contains 75 per cent copper and only 25 per cent nickel) assures it a market in every use of alloys developed for their whiteness, their rustlessness, and their resistance to corrosion; just as nickel's ability to impart strength, toughness, and machinability assures it a market in the alloys developed for better performance in industrial and engineering functions, and as its magnetic qualities assure it an established place in the electrical field.

Since 1850, approximately 1,000,000 tons of nickel have been produced



THIS IS SPEED

The turbines of S. S. Bremen drive her at better than 30 miles an hour. To do this, superheated steam is forced against the turbine blades with an impact velocity of 40 miles *a minute*. Blades and spacer pieces are of wrought Monel metal because it combines the physical properties of alloy steel with a complete immunity to rusting, retention of strength at high temperatures and resistance to the erosive effects of superheated steam.

and consumed for all purposes throughout the world. The production data are interesting. Only 14,000 tons were produced from 1850 to 1885. During the next quarter of a century, the total reached 230,000 tons. The next decade, including the war period with its vertical rise in consumption, saw the figures jump to 357,000 tons. Since then, the average has been 32,000 tons a year, with a peak of 68,000 tons in 1929, greatly exceeding the peak of war-time production, and a low point of 8200 tons reached during the depression of 1921.

The public generally thinks of nickel as a metal for coinage and for plating. Only about 5 per cent of the entire world production has been used for nickel plating—or 50,000 tons. The amount of surface thus plated would be equivalent to a road 164 feet wide encircling the globe at the equator. Incidentally, the discovery which made plating possible was made by Michael Faraday exactly a century ago; it is the principle of electro-chemical decomposition.

Nickel is by no means all things to all men. In many places where it functions best it has definite rivals, and in many instances it needs the coöperation of other alloying elements to give the desired performance; but it is a friendly element which mixes well with other metals, and there are so many instances in which it is a necessary, or at least highly desirable

factor, that the cumulative effect provides a diversified and constantly growing market for this metal.

In the post-war discovery and development of this composite market, the nickel industry has had invaluable help from research scientists who have worked their way to nickel from far beyond the horizon of the industry. At the same time the men within the industry have carried the main burden and have done much of the trail blazing. Their story, which includes the formation of The International Nickel Company of Canada, Limited, and the modernization of the mining and metallurgical operations through a $50,000,000 expansion program, will be told in the next and final instalment of "The Story of Nickel."

A NOTE ON THE PRECIPITATION OF NICKEL AND COBALT AS SULFIDES IN QUALITATIVE ANALYSIS

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In the usual scheme of qualitative analysis, nickel, cobalt, manganese, and zinc are precipitated with H_2S or $(NH_4)_2S$ from ammoniacal solutions. This procedure often results in the formation of colloidal CoS and NiS, which is very undesirable.

Haring, with Westfall and Leatherman [*J. Am. Chem. Soc.*, **52,** 5135–41 (1930)], has found that at a pH of 4.4 or slightly lower in an ammonium acetate solution, both of these elements will give perfectly compact and easily filterable precipitates.

In an effort to arrive at approximately this pH and get a good precipitate of these two elements we have made the following change in the usual procedure:

After precipitating iron, aluminum, and chromium with NH_4OH, the solution is made just acid with acetic acid, and 5% $(NH_4)_2S$ is slowly added until precipitation is complete. All of the above elements are completely precipitated in a good granular form.

This was tried in our class of 400 students and in only four cases were colloids formed. We suspect that in these cases the students failed to acidify with acetic acid. In the procedure followed, the iron, aluminum, and chromium hydroxides were filtered off before testing for the other ions. But even if these are all mixed, as in the A. A. Noyes procedure, the method outlined may still be used. In this case the hydroxides will dissolve in the acetic acid but will reprecipitate with the $(NH_4)_2S$.

Language is only the instrument of science, and words are but the signs of ideas.—JOHNSON

THE RELATION OF THE SCIENTIFIC "HUNCH" TO RESEARCH*

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Replies from several hundred research workers and directors of research indicate that certain conditions are definitely favorable to creative mental effort while others are equally unfavorable. Representative replies have been quoted at length. The mind must be well provided with facts, but periods of rest or temporary abandonment of a problem are quite essential. A mind which is saturated with facts bearing on a problem may reach a solution while on the fringe of consciousness.

. . . . . .

At a recent intersectional meeting of the American Chemical Society, there was held a symposium on the Organization of Industrial Research. The directors of research who were present spoke, with the authority born of experience, on the organization of research, selection of problems, and kindred subjects. When the discussion turned on such questions as scientific intuition, and the most favorable conditions for the mental activity of the research worker, unusual interest was aroused and many entered into the discussion. It was evident, however, that this was a question to which chemists had devoted comparatively little study. Few of those present seemed familiar with the literature of the subject.

The pursuit of any piece of extensive chemical research involves a mechanical side and a mental side. The mechanical side is concerned with methods of analysis, manipulation of apparatus, and all that highly important technic which is an essential part of the training of any chemist. Nine-tenths of the time in any research laboratory are and always must be taken up with such work. The mental side of research is concerned with initial planning; devising, in the course of the research, changes in these plans to overcome unexpected difficulties or to follow up unexpected developments; and finally interpreting the data obtained. Difficult pieces of research fail much more often from deficiencies in chemical insight than from any insurmountable difficulties in chemical manipulation. Mental effort can economize and direct experimentation but can never replace it. Each is a necessary supplement to the other. As Freeman says: "Experimenting does not absolve the scientist from the duty of thinking."

On the mechanical side there is an abundance of literature which is regularly consulted. On the mental side, however, there is much less that is directly helpful, and what there is seems to be unfamiliar to most chemists. Yet most of us realize in a general way that there is a tremendous variation in the efficiency and yield of our mental reactions under different condi-

* Presented before the Division of Chemical Education of the A. C. S. at Indianapolis, Indiana, April 1, 1931.

tions. Few chemists seem to be familiar with the interesting literature already available on this subject.

The present paper is an attempt to discover through the testimony of past and present leaders of science some empirical facts regarding the conditions favorable and unfavorable to the mental side of scientific research. We have drawn freely on a number of sources, including works on psychology, which throw light on our problem.

The philosophy of the scientific method is now a commonplace of science which is familiar to every chemist. Less study, however, has been devoted to creative mental effort, the bases of which are naturally laid in the elements of psychology. (See texts by Whewell, Carpenter, Ribot, Poincaré, Rignano, Lowes, and Downey in bibliography appended.)

Types of Research Problems

In one type of research work, generally with limited objectives, it is possible to obtain such complete data that only one conclusion is possible. Such a problem is for example: what conditions of temperature and pressure will give the greatest yield in a given organic reaction? With a little intelligent planning and trials of several combinations of temperatures and pressures, one could evidently be certain of solving the problem. Professor C. F. Chandler of Columbia University once said that one could solve any problem in chemical research by obeying two simple rules, namely: "To vary one thing at a time, and to make a note of all you do." This is evidently the type of research that he had in mind.

The type of problem to be considered in this paper, however, is that in which the possibilities are almost infinite and in which it is hardly possible to accumulate by mere industry sufficient data for its solution. Classical examples of the working out of such larger problems are the rational explanation of the motion of the heavenly bodies as solved by Newton, and the theory of evolution as worked out by Darwin and Wallace. In each case it would evidently have been impossible to marshal such complete data that the answer would stand out as self-evident. In these cases, as C. J. Davisson says, "A flash of genius is necessary." It is this flash of genius that we are attempting to study.

Evidently in this common type of problem, success can hardly come by mere industry. A mass of data is not necessarily the answer to a problem. As information is accumulated, judgment is constantly necessary to sift and interpret it, and a trained mind with scientific insight will often grasp the essential factor even before it has been completely established by the evidence. This conclusion may then be confirmed by comparatively few further experiments.

It is this *leap of the imagination* over the gaps in the evidence to the correct solution that is an essential part in the successful attack of many re-

search problems. Such leaps may be large or small. They may aid in overcoming a small obstacle or in jumping to the final solution of the whole problem.

Two Types of Research Workers

Since beginning the present investigation our attention has been called to three lectures by Wilder D. Bancroft on "The Methods of Research," delivered at the Rice Institute. Bancroft's lectures are an excellent exposition of the methods of research and in particular of the essential part which that "flash of genius" or hunch plays in most scientific progress. He says:

> The first of the two general methods of research is [that]....in which one first gets one's working hypothesis and then accumulates data to test it. The second general method is [that] in which one accumulates data until the general theory underlying them becomes obvious. I am going to say that those who accumulate facts are "accumulators" and those who start early with working hypotheses are "guessers." I am using the word guess as it is used in New England and not as it is used in Central New York. I do not mean the result of pure chance, such as flipping a coin. I mean by guess, making the shrewdest judgment one can from facts which are not entirely adequate. Guess is the word used by Newton in the same sense, so it has been in good use for several centuries.

Bancroft then proceeds to justify his guesser and accumulator classification. We select but two of his descriptions of scientists. He quotes Tyndall's description of Faraday's work.

> In the researches now under review the ratio of speculation and reasoning to experiment is far higher than in any of Faraday's previous works. Amid much that is entangled and dark we have flashes of wondrous insight, and utterances which seem less the product of reasoning than of revelation....The manner in which Faraday himself habitually deals with his hypotheses is revealed in this lecture. He incessantly employed them to gain experimental ends, but he incessantly took them down, as an architect removes the scaffolding when the edifice is complete. "I cannot but doubt," says he, "that he who as a mere philosopher has most power of penetrating the secrets of nature, *and guessing by hypothesis* at her mode of working, will also be most careful for his own safe progress and that of others, to distinguish the knowledge which consists of assumption, by which I mean theory and hypothesis, from that which is the knowledge of facts and laws."

Turning to Pasteur, Bancroft states: "Pasteur was a brilliant guesser and a great fighter."

The same division of creative thinkers into two such types has been recognized by Downey, Ribot, and others. It is interesting to see a similar distinction made between men of action. General Charteris says in comparing Earl Haig with Lord Kitchener:

To Haig the essential method of arriving at a decision was complete knowledge and study of all the factors, and then a considered and most firmly held judgment. In temperament and characteristics, Haig and Kitchener were totally distinct. To Haig's reasoned arguments, Kitchener had nothing to offer except unconscious mental processes, arriving with amazing frequency at correct conclusions. With Haig it was logic; with Kitchener, instinct or genius. . . . Their minds—even though they approached each problem from a different angle, and by a very different process—again and again arrived at the same conclusion.

Poincaré makes a similar distinction. As quoted by Carmichael, he says:

It is impossible to study the works of the great mathematicians, . . . without noticing and distinguishing two opposite tendencies or rather two entirely different kinds of minds. . . . The one sort are above all preoccupied with logic. . . . The other are guided by intuition and at the first stroke make quick but sometimes precarious conquests like bold cavalrymen of the advance guard. . . . The two sorts of mind are equally necessary for the progress of science.

Among those who answered the present questionnaire the two types are often clearly defined. Some of those who answered, unconsciously pictured themselves as consistent accumulators, others as guessers.

Newton is said to have stated that no great discovery was ever made without a bold guess. The place of scientific intuition, of this "bold guess," "flash of genius," or "hunch" in the scientific research of the past is covered by the following quotations taken from Bancroft's paper. Tyndall writes:

First of all, I am blamed for crossing the boundary of experimental evidence. This, I reply, is the habitual action of the scientific mind—at least of that portion of it which applies itself to physical investigation.

And Gilbert says:

In the testing of hypotheses lies the prime difference between the investigator and the theorist. . . .

The practical questions for the teacher are, whether it is possible by training to improve the guessing faculty, and if so, how is it to be done. To answer these, we must give attention to the nature of the scientific guess considered as a mental process. Like other mental processes, the framing of hypotheses is usually unconscious, but by attention it can be brought into consciousness and analyzed.

The great investigator is primarily and preëminently the man who is rich in hypotheses. In the plentitude of his wealth he can spare the weaklings without regret; and having many from whom to select, his mind maintains a judicial attitude. The man who can produce but one, cherishes and champions that one as his own, and is blind to its faults. With such men, the testing of alternative hypotheses is accomplished only through controversy. Crucial observations are warped by prejudice, and the triumph of the truth is delayed.

Four Stages of Research

Graham Wallas, in his book, "The Art of Thought," largely following Helmholtz, divides research into four parts. First, *preparation*, in which this problem is "investigated in all directions" both by reading and experiment. Second is *incubation*. In this period the mind goes over the information acquired during preparation. Much of this mental action is unconscious and is, in fact, a sort of mental digestion and assimilation of the facts acquired, together with all other facts in the mind which may bear upon the problem.

"The third, consisting of the appearance of the happy idea, together with the psychological events which immediately preceded and accompanied that appearance," he calls *illumination*, corresponding to our "hunch." The fourth stage is *verification* in which the "happy idea or working hypothesis which seems to unify and explain all known facts is tested by experiment." As Huxley says, "The man of science has learned to believe in justification, not by faith but by verification."

We may not disregard the importance of preparation and verification. Cohen says:

> The seed which ripens into vision may be a gift of the gods, but the labor of cultivating it so that it may bear nourishing fruit is the indispensable function of arduous scientific technic.

Chapter IV of Wallas' book touches directly on the subject of this paper and is particularly well worth reading.

It is our object here to study the periods of incubation and illumination, which are, respectively, the mental preparation for the hunch and the appearance or recognition of the hunch by our conscious minds.

Classical Examples of the Scientific Hunch

A clearer understanding of what Wallas has called the periods of incubation and illumination, which latter we have designated the scientific hunch, may be gained through several typical examples.

Leubá gives the two following descriptions:

> H. Poincaré in an article on invention in mathematics remarks that the most striking feature of mathematical invention is "apparent sudden illumination." Of one of the greatest of his discoveries, the *functions fuchsiennes*, he wrote: "I had been endeavoring for two weeks to demonstrate that there could exist no function analogous to those I have since called *functions fuchsiennes*. Each day I spent an hour or two at my working table...but I came to no solution. One evening, against my habit, I drank some black coffee. I could not sleep; ideas crowded my mind; I felt them knocking against each other, until two of them hung together, as it were, and formed a stable combination. In the morning, I had established the existence of a class of functions. There remained merely to set down the results and that was done in a few hours."

Prince Kropotkin had for several years been intensely interested in the physical conformation of Asia. He writes in his memoirs that he had "marked on a large-scale map all geological and physical observations that had been made by different travelers and that he had tried to find out what structural lines would answer best the observed realities." This preparatory work required over two years.

"Then followed months of intense thought in order to find out what the bewildering chaos of scattered observations meant until one day all of a sudden the whole became as clear and comprehensible as if it were illuminated with a flash of light.... There are not many joys in human life equal to the joy of the sudden birth of a generalization illuminating the mind after a long period of patient research."

Von Helmholtz, the great German physicist, speaking on his seventieth birthday, described the way in which his most important new thoughts had come to him. He said that after previous investigation of a problem "in all directions . . . happy ideas come unexpectedly without effort like an inspiration. So far as I am concerned they have never come to me when my mind was fatigued or when I was at my working table." Helmholtz found that rest was necessary for the appearance of scientific inspiration and that brilliant ideas often occurred to him in the morning after a night's rest.

They came particularly readily during the slow ascent of wooded hills on a sunny day.

For years, through intense and unremitting observation, Darwin had been accumulating masses of facts which pointed to a momentous conclusion. But they pointed through a maze of baffling inconsistencies. Then suddenly the flash of vision came! "I can remember," he tells us in that precious fragment of an autobiography, "I can remember the very spot in the road, whilst in my carriage, when to my joy, the solution occurred to me," and then and only then, with the infinite toil of exposition, was slowly framed from the obdurate facts the great statement of the theory of evolution. (*Lowes*)

A more general description of the hunch is given in the following report by Platt of the Symposium on Industrial Research:

The question of "chemical hunches" came in for much discussion, even though not directly connected with the symposium. Every worker with a spark of the true scientist in him has had the experience of the appearance of the hunch. He has been working on a problem continuously without success. He may even abandon the problem for a time. Suddenly the solution comes to him. He thinks it over and it seems eminently reasonable from every point of view. He tries it and it works! Out of an almost infinite number of possible modes of attack, the right one has dawned upon him without effort—seemingly from Heaven!

Many of those present believed that it was possible definitely to encourage the appearance of the hunch by purposely creating favorable conditions. In general, a man incessantly busy with one activity or another during all his waking moments is not one to whom such ideas often come. We can drown out messages from the subconscious mind

by keeping our conscious mind constantly occupied or too greatly fatigued.

Great differences were reported as to the most favorable conditions for the appearance of the hunch. L. H. Cone advised work in the laboratory. The hunch would come while the work was in progress. Another chemist said that the most valuable time that he ever put in for his employer was spent sitting with his feet on the window sill looking out of the window.

Most reported that hunches came during periods of apparent idleness—following, however, long periods of intensive work. One reported the system of going over the problem just before retiring for the night. The solution would often become apparent in the morning.... This is a question which is worthy of further study both from the psychological and the chemical points of view.

The Hunch Defined

It is realized of course that the hunch, illumination, or revelation shades imperceptibly into conclusions arrived at by more conscious reasoning. A clearer understanding will be obtained from the examples quoted than from a definition, but we nevertheless attempt a definition as follows: *A scientific hunch is a unifying or clarifying idea which springs into consciousness suddenly as a solution to a problem in which we are intensely interested. In typical cases, it follows a long study but comes into consciousness at a time when we are not consciously working on the problem. A hunch springs from a wide knowledge of facts but is essentially a leap of the imagination, in that it goes beyond a mere necessary conclusion which any reasonable man must draw from the data at hand. It is a process of creative thought.*

Dallenbach, in a private communication, has given a more concise definition as follows: *A hunch or an intuition is a judgment the bases or premises of which are unknown or not clear to the individual having the hunch.*

Many of those who answered the questionnaire which we sent out in connection with the paper, criticized our use of the word hunch. It is significant, however, that no one suggested a better term. Revelation and inspiration are used by many writers but these suggest aid from the spiritual world which we specifically do not mean to imply. Bancroft's "guess" and his definition have already been given, but guess suggests to the average reader a student guessing at the answer to a question put to him in a recitation, entirely without those periods of preparation and incubation or mental digestion which give the typical hunch its value.

What is called "the gambler's hunch" is not based on any facts or judgment whatever and is quite distinct from the term "scientific hunch" which we have described here and which has already been widely used by scientists. For example, Millikan says: "Einstein's $h\nu$ formula was originally a mathematical hunch."

Possibly Wallas' term "illumination" is better than "scientific hunch" since the former has no extraneous implications. If we were to coin a

new word for it we should perhaps adopt Bancroft's suggestion to go back to Archimedes' exclamation and call it a "eureka."

Questionnaire Returns

As a direct experimental study of this question is obviously impossible, the best mode of attack seemed to be through a study of the research methods of a considerable number of scientists of admitted leadership. For this purpose, a questionnaire was sent out to 1450 scientists. Two hundred of these were directors of research laboratories and the rest were selected from the latest edition of "American Men of Science." While most of these were chemists, we included a number of physicists, mathematicians, biologists, and psychologists.

The first page of the questionnaire folder contained examples of hunches taken from the writings of Helmholtz and Kropotkin and from the report of the Syracuse symposium already quoted.

A total of 232 replies was received. Among those who replied are some of the best-known contemporary American scientists in academic, industrial, and government work. Unfortunately, many of those replying specified that their names should not be used.

We repeat that the answers which follow come not from freshmen nor from impractical dreamers, but from men, all of whom have demonstrated their ability as research workers. We feel therefore that these observations and the practical conclusions arising therefrom are worthy of careful consideration by (1) those who are carrying on scientific research, (2) those who direct other research workers and control conditions under which they function, and (3) those who train students for research work.

The Answers

There is space here for only a few of the replies received. Each reply here published is representative of many similar ones sent in. A supplement to the present paper has been prepared giving several hundred additional extracts from answers received to these questionnaires. A few brief comments are also included. This supplement will be sent without charge by either of the present authors to any one interested.

Question 1. *Have you ever received assistance from the scientific revelation or hunch in the solution of an important problem? Frequently....Occasionally....Never....*

33% report "Frequently"; 50%, "Occasionally"; and only 17%, "Never."

Question 2. *If so, please describe one or more typical instances as fully as possible.*

Of many interesting instances which were cited, the following may be regarded as typical:

While a graduate student at "Tech" I was engaged in the study of the problem of determining the successive ionization constants of ortho and pyro phosphoric acids. A very promising method (at that time direct pH measurements were not made) was the direct measurement of the hydrolysis of the ammonium salts of these successive acids. This was attempted by shaking the hydrolyzed solution with an immiscible solvent which would dissolve ammonia. Chloroform was found to be suitable, and the attempt was made to measure the partition coefficient of ammonia between water and chloroform. Upon shaking the ammonia solution with the chloroform, emulsions of water in chloroform were obtained which completely vitiated the method.

After intense concentration and many vain attempts to overcome this difficulty, I reluctantly decided to abandon the method. I was tired and discouraged and hungry. I decided to go down town and have a thick beefsteak at Charley Wirth's and completely forget my work for the time being. Freeing my mind of all thought of the problem I walked briskly down Tremont Street, when suddenly at a definite spot which I could locate today—as if from the clear sky above me—an idea popped into my head as suddenly and emphatically as if a voice had shouted it in these words: "In pharmacy and in industry, we clarify emulsions by means of a high-speed centrifuge; such a method would be impractical in a thermostat. But if rapid whirling for a brief time will do it, why will not slow rotation for a longer time accomplish the same result?"

Whirling about on my heel, I returned to the laboratory, placed three liter bottles of the materials on the stirrer of the bath in such a way that the solutions were rotated bringing alternate layers of water and chloroform in contact with the walls of the bottles. I then went to lunch carefree, but eager to learn the result. Upon my return more than an hour later, I was delighted to find that the two phases had separated perfectly. The method was applied with success and soon led to a definite solution of my problem. I have since applied this method successfully when troubled with emulsions in alkaloidal analysis. (*G. A. Abbott*)

Discovery of anti-knock effect of metals in colloidal solution in kerosene. This immediately preceded discovery of effect of tetraethyl lead (by Boyd and Midgley). This work followed the failure of almost innumerable experiments; no detailed description can be given; it was merely a "hunch." (*A. R. Albright*)

My most recent experience was a problem on which I had given continuous thought and labor until my mind and body were completely fatigued. Decided to abandon the work and all thoughts relative thereto, and then on the following day when occupied in work of an entirely different type, an idea came to my mind as suddenly as a flash of lightning and it was the solution. In fact, the information was so *positive* that I *knew* it would work before the final tests and experiments were carried out. Like other "hunches" I have experienced in my research work, the utter simplicity made me wonder *why* I hadn't thought of it before. (*E. R. Barnes*)

In spite of the apparently sound objection against the feasibility of the "hunch" I still felt intuitively that it would work. Accordingly, I pro-

ceeded privately to try it out and as a result hundreds of millions are used yearly with entire prevention of the trouble. (—)*

In trying to develop a method for the treatment of a potash mineral a considerable amount of time had been spent in laboratory and library. No chemical method tried had been economically feasible. After about four weeks on this problem, I had occasion to take a very early train (3.50 A.M.) to another city. While riding, a thought of a totally different process from those I or my associates had been considering came to me. I made a rough outline of the basic ideas and the development work on the process has since proved it to be both technically and economically possible. (*J. F. T. Berliner*)

In flying over smooth water, I observed the image of the plane in the water. This could be seen at an altitude of eight to ten thousand feet. A few days later, while resting and loafing on the beach, it dawned on me that this image would photograph in motion pictures from the plane and establish the vertical position in ballastic studies. This idea was most useful in determining facts previously unknown. (—)

My whole education and experience in life in my chosen profession of chemistry have been technical and practical rather than scientific. I could name many incidents of "hunch." Perhaps the most important commercially successful one was the invention of the dyeing of "Sun Fast" colors on window shades for which process I have received considerable recognition.

I had worked for several years and almost continuously on this problem, having finally given it up as a practical proposition, *i. e.*, that it could not be done. One day I was examining some samples of raw cotton, among them being several of a dark écru color instead of white. These samples the party said were called "sanded" cotton colored by nature through falling upon red soil, the color being beaten in by the rain, and not removable by any method of bleaching known to the arts. Instantly the "hunch" flashed in and said this is the way to produce what you have spent long months of work on. And so it proved to be—many shades of color having been developed on the central principle involved.

The underlying principle was patented and gave rise to a very profitable industry still flourishing. (*Victor G. Bloede*)

I remember distinctly, while head of the laboratories of the old U. M. C. Co. in Bridgeport, working on a problem that had bothered them for years (probably 15 or 20 years). We worked on it quite intensively for several months; and after that only occasionally. One day, while sitting at my desk doing nothing, and thinking about other matters, a thought flashed through my mind. I immediately left the office; went out into the plant by myself, made a few tests, and solved the difficulty. I then went to the manager and told him about it and he would not believe it until I showed him some samples, as it seemed too simple. I have had the same thing happen since then at different times, but never quite so pronounced as at that time or on a problem upon which we had worked for so long a time unsuccessfully. (—)

* Where the scientist asked that his name should not be used, we have placed a dash after the quotation of his answer. In this and some other instances the scientist requests also that the specific problem should not be mentioned.

One instance of a hunch was while dodging automobiles across Park Row and Broadway, New York. My mind was absolutely blank (scientifically) while physically alert jumping about. This shows that a complete dismissal of the subject will relieve cases of mental blockade. (*V. Coblentz*)

The idea of electro-casting refractory blocks came to me after viewing a small furnace in which a test had been made and while walking away to leave the room. It came with such a shock I remember the exact position quite clearly. As far as I remember, I had not been concentrating on the problem. (*G. S. Fulcher*)

Example: Minerals Separation vs. Miami. Highly magnified moving pictures of the coalescence of free-rising air bubbles in pure water. Bubbles rose so fast that only one or two exposures of a single bubble could be obtained even at 60 or 80 pictures a second. Spent weeks and several thousand dollars on higher speed camera, etc. Pictures still bad at 150 per second. Finally slept out a hazy notion of bubbles rising in a column of smoothly down-flowing water, tested roughly and finished working apparatus next day. Beautiful pictures with 8–15 views of single bubble resulted and proof of violent coalescence in $^{1}/_{12,000}$ sec. (*Wm. M. Grosvenor*)

I quote as follows from "The Autobiography of an Amateur Inventor": I studied the problem of halftone process. I went to bed one night in a state of brain fag over this problem and the instant that I awoke in the morning saw, before me, apparently projected upon the ceiling, the completely worked out process and equipment in operation, etc. (*Frederick E. Ives*)

After twenty-five years' work on the mechanism of the sodium malonic reaction and after a month's vacation, as I was dressing after a bath in the sea, I said—"I have worked on this for twenty-five years and am no nearer the solution than when I started." Then the explanation, essentially complete, sprang into my head. This was the unconscious working out from new data obtained in an experiment tried that year. It was afterward proved to be correct by me. (—)

A professor of organic chemistry issued a problem to a senior class of which I was a member. I worked hard at it at intervals for some time. One of my intensive efforts to solve the problem occurred one night before retiring. Presumably, my subconscious mind continued to work as I snuggled into my pillow. Suddenly (and apparently after I had begun to doze) a number of essential facts bearing on the problem flashed to me. I got up (though later, I could not recall having done so) went to my desk and made (as if in the dark) rough and irregular notes of these facts or ideas. The next morning the experience assumed the form of a hazy dream, the details of which I heartily wished I could recall—was astounded to find the notes on my desk and to recognize them as my "dream"(?). They enabled me to hand in the first solution of the problem.*

* This is similar to Banting's experience with the idea that led to the discovery of insulin.

In the making of methyl acetate it was found that methyl alcohol, calcium acetate and sulfuric acid would not react to give good yields though under similar circumstances amyl alcohol gave good yields of amyl acetate. The "hunch" of adding water to the mixture, which was found to increase the yield from 40 to 90%, came in a round-table discussion of the matter. (*R. H. McKee*)

The process and the product of this process of my invention were too costly. I had discussed the entire matter for several hours with the engineer in charge of the work. I went to the hotel, had dinner and thought the situation over. I went to bed and slept for several hours. At 3 o'clock in the morning, I awakened with an entirely new process clearly before my mind's eye. I arose and wrote out a patent disclosure. A patent has been since granted. A portion of what I saw as a flash was wrong, but the main principle proved to be valuable. (*E. B. Spear*)

For six months, I had been working in the laboratory days and in the plating room nights to work out a method for controlling the composition of the plating bath so that the deposit might have a definite composition. I had consciously tabulated ten variables and had made observations relating to each. I came to the plant one Sunday morning about 9 A.M. when no one was around. Suddenly it dawned on me that one of the variables was more important than all of the others together. (—)

Wheel Design.—The wheel from earliest time until October, 1929, was a structure designed empirically—even the wire wheel of automobiles. In my standardization work for our company, it was desirable to control the design technically—as we have many designers who enter on this problem. We now make and use over 1000 different kinds of wheels—over 1,500,000 wheels a year, at a manufacturing cost of over $10,000,000. In order to make a huge saving which nets about $2,000,000 a year the importance of the technical wheel was evident. Therefore, as chairman of the wheel committee, I found no guiding data in textbooks, etc., and had to make a solution. After trying vainly to get one by regular well-known applications of mechanics for over 10 months, I suddenly got a "hunch" which after four and one-half hours of application thereafter proved the correctness of the suggestion and this resulted in a beautiful *new* solution which has proved itself correct in every detail on research tests, as well as practical tests. (*O. B. Zimmerman*)

I had been studying to improve circulation of oil in pipe coils for several days. Sunday in church the correct principle came like a flash as the preacher was announcing the text. I put it in practice. It was correct. Strange to say I have always remembered the text and the sermon. (*D. Wesson*)

We can see in many of these instances the characteristics of the typical hunch. The hard work on the problem and desire for its solution, abandonment of the work and attention to something else, then the sudden appearance of the idea with its sense of certainty. Sometimes there is a feeling of marked exhilaration and often surprise that the idea had not been thought of before.

Question 3. *Please describe conditions under which these revelations or hunches usually appear, giving: (a) time of day, (b) your occupation at the moment, (c) mental and (d) physical condition such as complete relaxation, fatigue, etc., (e) time which had elapsed since your attack of the problem, and (f) any other details which seem of interest.*

In the replies to this question and the next two, lie the suggestions of greatest practical usefulness.

The general conditions described are good health, relaxation, freedom from worry, or some form of mild exercise.

Some psychologists hold that some parts of the brain perform their most useful work in the interval of drowsiness between waking and sleeping. (See, for example, Varendonck's work.)

Among occupations mentioned during which hunches often appear are: shaving or dressing, driving automobile, gardening, fishing, golfing, riding in train, playing solitaire. Several say their best ideas come to them while walking between their home and the laboratory morning or evening. Several mentioned walking in the country. A considerable number state that hunches have come when listening to music and a few refer to the related condition of listening to a sermon.

Abel relates:

> It is an old saying ever since Archimedes solved the problem of specific gravity in his bath tub...that discoveries are not made in laboratories but in the bath tub, or during an afternoon or evening walk as in the case of Helmholtz, or in the watches of the night when the puzzled brain will not quiet down, as has been the experience of so many investigators.

In these cases, the essential features, common to all, are evidently pleasant relaxation and freedom from mental interruptions.

Some state definitely that their best ideas come in the morning, others that they nearly always come in the evening. L. M. Larsen says that his come when resting during the noon hour after a hard morning's work.

Several say that their hunches come to them only when alone. A larger number find discussion with others stimulating to thought. Some refer especially to the stimulus of explaining a problem to students. Most find that these discussions bring out the best thoughts if friendly and not conducted in a critical spirit.

Some of the replies of special interest touching on this question are the following:

> Several ideas culminating in inventions were "born" just before retiring or falling to sleep—in a period of complete relaxation and distant from the laboratory.
>
> These ideas do not come so frequently while at work or under tension. The idea soil is quite fertile also when consulting books, such as *Chemical Abstracts*, in the library. A quiet, restful, dreamy mood, and when

surrounded with books generally in the evening when alone in the study room—these are the optimum conditions for a "hunch." (—)

My experience is uniform in one particular. The hunch has invariably come at night after retiring for sleep. In such cases, my condition has been one between wakefulness and sleep and the insight has been entirely effortless. Often in such states, pertinent facts long since forgotten have come to the surface. In one case at least, the oblivion has been so complete that on the following morning, I have found it necessary to look up the fact to assure myself if it was really a fact and not a dream.

Aside from the semi-somnolent condition as a Nidus of creative thought, I have sometimes found driving a motor car to be effective, but have never deliberately resorted to this. This would seem to me to be most strange. One would say that the two conditions, driving a car—semi-sleep, are wide apart as the opposite poles. No hunch has ever come to me in the presence of any other person. (*L. W. Andrews*)

I can't say that the time or condition is particularly well defined. To the best of my knowledge the so-called hunches may appear at any time under nearly any circumstances but in all cases very unexpectedly.

You can force logical deductions from past experience, but the new ideas are largely spontaneous. You can put yourself in a favorable condition to receive the hunch, by deliberately thinking along certain ideas. A hunch is partly dependent on past experiences but in many respects it seems like pure luck. (—)

Personally, I believe hunches are highly subject to the personal equation and I seriously doubt the value of this questionnaire. (—)

(1) Late at night after working intensively for some hours, relax and then the facts seem to tumble into order.

(2) When trying to explain something to another. (*G. G. Brown*)

The best "hunches" usually come early in the morning after a good night's rest or after indulging in some sort of recreation for a few hours. It seems that the best condition is after a period of complete relaxation and immediately following a period of very intensive work on the problem. Satisfactory hunches sometimes "arrive" while discussing the details of a problem with the men who are working closest with it, or immediately after such a discussion, while one is trying to outline the problem and see that all the important leads have been followed. (*H. J. Barrett*)

My mind is always most active just before and just after an attack of gout (of which I have one of the mild varieties). This is too regular to be ascribed to coincidence.* (*E. T. Bell*)

I have had a great deal of interest in this subject for some time, and have studied my own ideas as well as those of other men doing research work. So far I have not found one authentic case in which the worthwhile ideas appeared to come from the subconscious mind although many men have given me their opinion that ideas do come from this source.

All valuable ideas that I have had have come as a result of a very great

* The great English master of medicine, Sydenham, is reported to have said, "More wise men than fools suffer with gout." (*Chideckel*)

deal of conscious effort. I find it necessary to spend hours or days in turning over the various factors of a problem before a solution is reached. Much of this time is spent in repetition but eventually an answer is obtained. I believe that I simply consider possibilities and discard one after another until finally I find one that meets all of the requirements. (*D. B. Bradner*)

To work best, limit your social activities, severely, and read your scientific periodicals instead. For recreation, read the literature or indulge in music—anything rather than in keeping late hours in chatter. (*H. T. Clark*)

I have never had much success in developing "hunch technic" in any of my associates. It is something inherited or acquired very early in life or else lacking forever.* (*W. F. Davidson*)

In such "revelations" nothing should be considered impossible. Everything should be tried. "The fool did not know it could not be done so he went ahead and did it." (*G. K. Falk*)

(*a*) Usually at night.
(*b*) Reading articles relating to the problem or possibly in some cases the article was only indirectly related.
(*c*) I must feel fresh and eager to study and think intensely.
(*d*) May be a year or so after all work has ceased, but usually it is the period when recreation is well under way. Worry and general depression make all thinking impossible. I must have the friendship and good will of others, in other words, a happy environment. (—)

The word "hunch" or inspiration would not be the correct words for my case but when I have problems that are baffling or difficult of solution I can get a clear solution often at night. It makes no difference the time of night but my mind must not be tired. My conscious mind does not seem to be so active but the subconscious mind is more active. I say this because very often the solution is not so clear the next morning unless I write down on a pad at night the solution. This presupposes that I have worked on the problem for some time and have followed all normal leads I could think of during the day but no conclusion reached. (*C. D. Geidel*)

I think most of my hunches have come to me in the early morning while in bed thinking about some problem on which I had done considerable work and studying. I am physically relaxed and rested; mentally, I am enjoying myself, thinking and planning the day's work. I have often said that I do more work before getting up in the morning than after. (—)

If I have a troublesome problem that is really big and hangs on for some time, I usually get it cleared up at night when I am trying to go to sleep. This is so common that I often have a pad and pencil on the little table near my bed to jot down ideas. Sometimes I tie my handkerchief around my arm to remind me of the idea when I get up in the morning. If the problem is a real big one, I often am able to line up a

* This raises an interesting question for science teachers.

whole program of attack before I quit. I do this in spite of myself, because I really want to get to sleep but cannot do it, because when I start dropping off to sleep another idea comes to mind and wakes me up. (*C. W. Hilly*)

I must say that my hunches come as the result of deliberate purposeful thinking about the problem, drawing consciously or unconsciously upon a broad knowledge of other closely allied fields. Any condition favorable to such thinking yields results but owing to the nature of my work which involves a great deal of administration, such periods can only come at night after the day's work is done. *Any employer of my services who wanted creative thinking oftener THAN ONCE A DAY, SHOULD RELIEVE ME OF MY ADMINISTRATIVE WORK, otherwise I might describe myself as a hard worker during the day on the mechanics of the job and a creative thinker at night on my own time.* (—)

In my experience, the most helpful thing is to talk with other chemists who have been successful *in other lines*, and to visit large factories engaged in *different lines* from my own. It is always an inspiration to see how others have solved their difficulties and it causes me to consider my problems less difficult than I had thought before. I can never go through a factory no matter how different from my own line without starting new lines of thought that are only vaguely related in their final conclusion to the suggestions that started them, though worthwhile things of some kind are apt to result. (*M. H. Ittner*)

I identify "scientific revelation" with "creative" thought in general. The origin of a new or original (to the thinker, at least) idea, whether it is the basis for a scientific discovery, a poem, a painting, a musical combination, an effective letter, or sermon, or even a witticism, or clever repartee, always comes as a flash of revelation, I believe. Naturally, therefore, if the problem required creative thought, the "hunch" was an essential step in its solution. Incidentally, the *importance* of the problem is irrelevant in connection with the nature of creative thinking.

Since the new idea has a greater appeal to the attention than the details incidental to occurrence, it is difficult to recall and describe them satisfactorily. The case is analogous to that of any spontaneous emotional experience: the one who feels often has difficulty in dissecting the feelings. It may be remarked, however, that the ideas that give me the greatest immediate satisfaction, are often those that occur in connection with somebody's else problem. That is to say, the anxiety to solve one's own problem may tend to defeat itself by preventing the smooth and pleasurable flow of mental images suggested by the problem. Somebody's else problem on the other hand provides a starting point for thoughts that need not be hampered by ulterior considerations of duty, responsibility, etc. In the typical cases, the flow of ideas is greatest when the mental activity is quite spontaneous and is in a spirit of fun. (*E. O. Kraemer*)

Hunches in the solving of an important problem always came to me but only after a thorough preparation in the field, lasting weeks or even months. A merely cursory occupation will not produce that frame of mind in which sudden revelations make their appearance. I shall how-

ever make what I consider, from my point of view, the most important contribution to researches in the field, namely, that the appearance of hunches cannot be encouraged to any extent worth mentioning by merely purposely creating favorable outward conditions. In my opinion hunches depend only upon two factors: (1) a certain inborn disposition, and (2) a thorough concentration on the subject by untiring efforts, an enthusiastic attitude and broad vision, leading beyond mere selfish aims of personal gains. With these two conditions fulfilled, revelations will invariably come, the outward conditions of their appearance being entirely irrelevant. (—)

Most clear-cut hunches come in mathematical problems, or in mathematical formulation of physical or chemical problems. Mechanism not clear in my mind. Nearly all important ideas come as quick as a flash, faster than they could be expressed in words but always after long gathering and analysis of data and usually after considerable apparently unsuccessful thought on the subject. (—)

So far as I am personally concerned such ideas of value as have come to me sometimes arrive in the morning when I am shaving but come more frequently when I am sitting in the front seat of an automobile and someone else is driving on a country road, and most frequently though attrition with other minds. The suggestion which brings them is also very apt to come while I am reading. (*A. D. Little*)

Think the reading of experiences of others valuable, but when you are once on the job you must lose any self-consciousness and think only of what you are trying to do. (—)

Often a more daring conception than the usual product of my mind. Usually more "striking" than the product of orderly thought. My grandmother often had "hunches" that were so often correct that I took an early interest in the subject. My own "hunches" have often been of great benefit to me and are usually correct—usually, but not always. I often give greater attention to my "hunches" than to the conclusions reached by the thinking out of a problem, which probably means that I regard the working of my subconscious mind more highly than I do the working of my conscious mind. (*W. O. Snelling*)

Be alone, rested, comfortable, fed but not overfed; no stimulant. You may need a book or two of tables and data, but get away from everybody. The Monk of Mount Athos in solitude contemplated his gastric center; finally, the universe became like a crystal ball, completely visible and comprehensible in the uttermost parts. The monk had the right idea. (*A. O. Sabin*)

The most constructive and valuable work I do comes from hunches which are so powerful that I am impelled to carry them through or tell others to do so. Other work is just plodding and laying foundations of general knowledge. (—)

The hunch is the result of a successful attempt to raise the conscious mind out of the entangling web of other men's ideas called science, into a region of natural resourcefulness, while at the same time allowing the

subconscious mind to direct the conscious activities in accordance with scientific facts. (*M. C. Taylor*)

The two factors that seem to be involved are, first, so thorough a study of the problem and of the data that your mind is quite completely saturated with the subject. Then, second, a period of intermission or rest and an apparent solution or proper method of attack comes to your mind when you are not formally working on the problem and have no papers in front of you. Now as I see it, if this solution or method of attack comes to you while you are working on the problem and have your papers in front of you, you would regard it as perfectly normal and natural and would think no more about it. It is this period of intermission and the lack of any papers, diagrams, maps, or whatever may be involved that causes one to refer to it as a revelation or a hunch. Here I think is where we fall into error. This thing only occurs when your mind is completely saturated with the problem. It is so completely filled that it can take up the matter at any time intelligently, without reference to data sheets, diagrams, maps, or such external aids. Consequently, we are wrong in thinking that we do not have all these helps in front of the mind. They are probably more vividly in the mind when the aids are absent than they are when they are present, and you can approach a deeper concentration in thinking of the subject than you ever could with your eyes following data sheets, diagrams, or what not, and *it is this deep concentration that is the most valuable asset in the solution of any problem.*

We speak of thinking and try to divide it into conscious, subconscious, and completely unconscious, which I think is an error. In deep concentration on any subject you are not only unconscious that you are thinking but you are unconscious of everything else around you, and I am reasonably sure that if a man is conscious that he is thinking, then at that moment he is not doing any serious thinking.

The third thing, of course, is to approach the problem with a rested mind, which is a most valuable help to deep concentration.

You ask me for some personal illustrations. To give one connected with the early morning thinking when most of our actions are nearly automatic, I remember one morning I took my bath, shaved, took another bath, and in reaching out for a dry towel suddenly became aware that this was my second bath and that my mind had been deeply concentrated on a problem for half an hour. This, of course, broke the concentration and the mind dropped the problem, but if there had been a succession of dry towels, I might have gone on shaving and bathing indefinitely, and awakened with a revelation. I give this as an example not because there was a revelation then, the thing being interrupted, but because it gives a clear picture of what is going on. The mind is fresh; it is so full of the problem that there is no need to refer to anything and it is in deep concentration. It is working at the problem and has been. If it works until the solution comes, we are liable to forget that it has worked at all. I have had such revelations come, for example, in my berth in a Pullman, reading a detective story, but on one occasion I checked this, happening to know something of the time involved and the story I was reading, and I had been looking at the same page for close to three-quarters of an hour without seeing anything at all. These are not revelations any more than any solution of a problem you are working on is a revelation. They

are simply cases of a fully rested mind, in very deep concentration on a problem, with all the data in front of you in your mind's eye, and I see nothing very remarkable about them except the depth of concentration you can reach if there is nothing outside to disturb the mind. With a rested mind soaked full of data on a problem, and in deep concentration, I would expect a man to solve a problem if he ever can solve it. In these revelations and hunches what we are so liable to forget is, that the mind is working, that it is working its hardest, and that it has the data to work on. (*J. E. Teeple*)

After these hunches I always felt intensely happy and the sensation of fatigue, if any, disappeared entirely for a long period afterward. They were always followed by an intense working period, in which the development of the ideas brought up by the hunch were carried to a further point than previously. (*M. P. Walle*)

Question 4. *Do you find any particular conditions definitely unfavorable for the appearance of such revelations? If so, please describe.*

In the answers to this question, we find a remarkable unanimity of opinion. Many of those who replied spoke very feelingly of the unnecessarily unfavorable conditions under which their mental activities must be carried on.

There are, of course, some general conditions, partly unavoidable, which are well understood to hamper mental activity. Many mention, for example, mental and physical fatigue, petty irritations, noise, worry over domestic or financial matters, depression, anger. There is nothing new in all this. As James said, "Worry means always and invariably inhibition of associations and loss of effective power."

Some of the newer factors listed as unfavorable are: intense interest in something else such as football and baseball games, bridge, etc.; too constant work on the problem, working under pressure, anxiety over the success of the research; too long periods of confined work, going stale. A. Clayton mentions one unavoidable factor which does not stand in the way of many of us, namely, "Periods of worldly success, if accompanied by a general softening of attitude, militate against the experience of hunches." We can all sympathize, though perhaps not agree, with George H. Gibson, an inventor, who lists among particularly unfavorable factors, "having to get to work on time."

The one thing that is more detrimental than anything else to creative thought of the best kind is interruptions of all kinds. This is stressed in the replies again and again. Equally bad is the *feeling that one may be interrupted* at any time. With such a feeling it is impossible to relax and let the constructive portion of the mind have full sway. A little observation of this condition as it exists in almost any laboratory will show that it is seldom indeed that a chemist can feel sure of several hours of uinterrupted thought. One of the best-known consulting chemists told us that for

him the best place for the advent of constructive ideas was a Pullman berth. Why? Because he could not be interrupted and *knew* that he could not be interrupted. Noise, cinders, discomfort, weighed nothing against the freedom from interruption. Another equally well-known chemist and teacher said that he did his best work at home after about 11 P.M. when all the family were in bed. He could work from that time until nearly dawn. Fatigue, etc., again counted as nothing compared with the glorious feeling of freedom from interruption.

Among interruptions the bugbear of many is found to be administrative duties. Maurice C. Taylor writes "administrative work is unfavorable, as is all of the stock in trade of the 'efficiency man.'" R. G. Bogue states that the most unfavorable condition is "the presence of persons to whom I *must* listen, and with whom I *must* converse." Again, "all administrative work and meeting people frequently to discuss routine matters is ruinous." (*E. T. Bell*) Another describes the unfavorable conditions as: "The crowded distractions such as make up the average business day." Finally the situation is well summed up by a teacher of chemistry who writes:

Yes, the distractions of executive work, the straightening out of snarls arising from human perversity, being compelled to listen to contentious or gossipy talk, are "conditions definitely unfavorable." Folin has well said that the research man "does not need a director, and should not be expected to become one."

Some one has said that the function of a bishop is to "suffer fools gladly and answer letters by return mail." Such functions have their reward; but they are not conducive to scientific concentration and revelation. (—)

Speaking of the problem of the best conditions for research work as raised in this questionnaire, J. W. Thornton says:

I believe the problem is of greatest importance; particularly, as it concerns the environment of the research man and his protection from worry and administrative details.

As an example of the benefit due to freedom from interruptions try going to the laboratory on a holiday. Note how easily many formerly complicated problems straighten themselves out, how smoothly the mind works, and how much work is accomplished with little effort. It is not too much for the research chemist to insist that he shall be allowed to work under favorable conditions and that he shall be properly protected from constant interruptions. Perhaps a research chemist may even have to choose between establishing a reputation as being good natured, easily accessible and mediocre on the one hand, or temperamental and markedly successful on the other.

Here is a field in which great improvements can be made not only by the individual chemist in modifying his own environment but also by the laboratory director in creating the most favorable environment for those expected to do constructive thinking.

Question 5. *Do you ever purposely invite such revelations by creating favorable conditions in any of the ways given below? If so, please describe....*
(*a*) *By temporarily abandoning the problem and taking up other work? If so, what type of work?*
(*b*) *By a period of idleness and complete relaxation not spent in attacking any other problem?*
(*c*) *By going over the problem just before retiring for the night?*
(*d*) *By special physical exercise or occupation?*
(*e*) *By the use of coffee, tobacco, or alcohol?*
(*f*) *Any other special means?* (*Kindly describe.*)

Many replies to this question were not entirely clear. However, 53% indicated that they purposely use some means to create conditions favorable for scientific hunches. Taking as 100% the number of those who purposely create favorable conditions, the expedients used are as follows:

By temporarily abandoning the problem and taking up other work, 60%.

By a period of idleness and complete relaxation not spent in attacking any other problem, 45%.

By going over the problem just before retiring for the night, 47%.

By physical exercise or occupation, 15%.

By the use of coffee $4\frac{1}{2}$%, tobacco 14%, alcohol $3\frac{1}{2}$%.

It is now generally admitted by health authorities that alcohol often hinders and only under the rarest conditions furthers real constructive thought. Several who reported that tobacco aids their thinking, state that they "do not recommend this method."

Question 6. *How definitely and completely does the revelation usually present the answer to you* (*i. e., in full detail or only as a central idea*)*?*

The overwhelming majority reported that the hunch came as the central idea only. Several stated that when once the central idea had presented itself to them, their minds then with great rapidity filled in the details. A small but notable minority reported that a hunch presented the plan to their minds complete in all its details.

Question 7. *Have you ever had a revelation that turned out wrong? If so, what is the proportion between correct and incorrect?*

Only 7% reported that their hunches always turned out correct. The remainder gave figures for the percentage of correct hunches varying from 90 to 10%. We have here of course a chance for a wide difference in interpretation of the meaning of the word "hunch." It may have been interpreted by some to mean any wandering idea that comes into one's head.

There is doubtless much truth in the comment of G. A. Abbott that correct hunches are more apt to be remembered and incorrect ones quickly forgotten. This is reminiscent of the statement of Charles Darwin that he was particularly apt to forget facts which did not fit in with his working hypothesis. One cautious chemist answering the question "Have you ever had a revelation which turned out to be wrong?" replied, "Not yet."

Question 8. *What is your explanation of the working of your own mind in the production of a revelation or hunch?*
(*a*) *Is the working completely conscious?*
(*b*) *Is it subconscious, i. e., on the margin of consciousness?*
(*c*) *Is it completely unconscious except for the moment of the appearance of the revelation?*
(*d*) *Is the revelation as it appears merely a logical organization of information already acquired, or does it contribute anything essentially new?*

The figures are: conscious, 19%; margin of consciousness, 28%; unconscious, 13%. Answer not given or not clear, 40%.

In these replies certain types of mind stand forth rather clearly defined. Those who report that their ideas come to them consciously usually seem to be of the "accumulator" type, and their answers to all the questions display this trend of thought. Many of them found the idea of the "hunch" to be very distasteful. The replies from other scientists indicate that they are typical "guessers." It is probably significant that 41% of the total who answered the questionnaire report that hunches come to them as a result of subconscious or unconscious thinking. The fact that many who replied were unfamiliar with the psychology involved, makes us hesitate to draw further conclusions from the percentages for "conscious," "unconscious," etc.

The majority of the answers to question 8 indicate that the hunch is a logical organization of information already acquired. In reply to the question regarding the newness of a hunch, many justly objected to the lack of definition of what we meant by "new." Perhaps the truth of this matter is best stated by Professor Lowes in "The Road to Xanadu" when he says, "that a pattern may be new although the pieces that compose the pattern are not new." Thought-provoking answers by mathematicians to somewhat similar questions have been reported by Fehr.

The reactions of psychologists toward the problem of the hunch are also of interest.

A letter was sent out by the present authors to a number of American psychologists asking:

1. What explanation do you favor for the appearance of the scientific hunch?
2. What are the conditions which are most favorable for the appearance of the hunch?

3. Do you believe a definite attempt should be made to create these conditions?

Some of the replies follow:

Your recent letter about the psychological interpretation of the scientific hunch interests me very much. It is one of the most important, as well as one of the most neglected, questions that has been raised for some time. (*L. L. Thurstone*)

I am very much inclined to think that we shall some day discover the damaging influence of too narrow a specialization. My own hunches or happy thoughts seem to come more easily when I am thinking about other things than the special problem concerned. This means that I must have other things to think about. Not infrequently when I am working at my hobby I have pop into my mind a happy thought for some problem which has been puzzling me in psychology. I have observed, too, that some of the great minds with whom I have had the privilege of working are characterized by a wide range of knowledge and interest. My guess is that range contributes largely to facility and adaptability in thinking. (*E. S. Conklin*)

Conscious and Unconscious Thinking

The process of thought receives treatment in every book on psychology. John Dewey's "How to Think" is considered a classic. Regarding the general process of thought we desire to invite attention here to only a few considerations.

Of the innumerable processes continually going on in the body, some, like the movement of the limbs, are conscious; some, such as the movement of the heart, are unconscious. Many body processes may at times be completely conscious, at other times unconscious. A familiar example of this border line is breathing which, if we so desire, is temporarily completely under control of the will but is normally completely unconscious. There are all possible gradations. In general, unconscious actions proceed more smoothly, quickly, and with less demands upon the body energy than conscious ones. For example, one walks more easily and gracefully when no conscious attempt is made to regulate one's movements.

In the case of human vision, only a small part of what is within the range of our vision is seen in clear detail. This part is said to be in the "fovea," that is, in the direct focus, while a much larger part is in the margin of vision where it is perceived, but only indistinctly.

Similarly, at a given instant, we are fully conscious of only a small part of our mental processes. A larger part is on the margin of our consciousness. Finally, there are many mental processes which are as completely unconscious as the functions of the liver. For example, you meet a man on the street of whom you have not thought in any way for years. Instantly your mind sorts out his name from the thousands of names stored in

your memory and presents this name to you in time for you to speak it. As Jastrow says: "The associative mechanism finds its sphere of activity largely in the subconscious realm."

Oliver Wendell Holmes has presented this undoubted fact clearly and convincingly.

I will give some instances of work done in the underground workshop of thought. We wish to remember something in the course of conversation. No effort of the will can reach it; but we say, "Wait a minute, and it will come to me," and go on talking. Presently, some minutes later, the idea we are in search of comes all at once into the mind, delivered like a prepared bundle, laid at the door of consciousness like a foundling in a basket. How it came there, we know not. The mind must have been at work groping and feeling for it in the dark: it cannot have come by itself. Yet, all the while, our consciousness, so far as we are conscious of our consciousness, was busy with other thoughts....

The more we examine the mechanism of thought, the more we shall see that the automatic, unconscious action of the mind enters largely into all its processes. Our definite ideas are stepping-stones; how we get from one to another we do not know....

Persons who talk most do not always think most. I question whether persons who think most—that is, have most conscious thought pass through their minds—necessarily do the most mental work.

The effort to solve a problem mentally is a constant series of trials and errors. The mind in searching for a solution considers in rapid succession a long series of conceivable answers, each of which is almost instantly rejected on account of some obvious objection. Finally in this process of trial and rejection we more or less accidentally stumble upon an answer to which the objection is not so obvious. The smooth course of trial and rejection is brought to a halt. Our attention is arrested. Further consideration only confirms the plausibility. The closely allied mental condition when working a puzzle is described by Ruger.

Bentley says:

It appears that the transcendent accomplishments of genius are due in large measure to condensations and ellipses on a large scale which reduce the elaborative procedures to their lowest terms. Intuition frequently means only defective observation of the rapid process of thinking.

Types of mind differ in the proportion of their thinking which is carried on consciously, on the margin of consciousness or unconsciously.

A time study of the outward activity of a research chemist could easily be made. From this we could construct a time chart of the workings of his mind—very imperfect to be sure, but still accurate enough to be helpful. Taking the total waking hours as a basis, we would find, of course, that a very small proportion is employed in such a way that the conscious mind is completely occupied with chemical research. A comparatively large

part of our time is spent in such a way that the fovea of our conscious mind is just sufficiently occupied to keep it from interfering with our real thinking. These periods include shaving, dressing, walking to work, routine chemical operations which no longer require close attention, waiting for a solution to filter or boil, walking about the laboratory, moments of relaxation, walking home from the laboratory, undressing, etc. Many forms of recreation likewise occupy the fully conscious mind just sufficiently "to keep it out of mischief," as, for example, easy exercise, riding on a train, gardening, attending a concert, etc.

It is under these conditions that our marginal consciousness, being free from conscious direction, usually turns either to those things that trouble us or interest us the most. It is at such times that much progress may be made in digesting and assimilating the details of our research problem if the latter is in such a condition that our minds will turn naturally to it.

The amount of time spent in this marginal thinking and its importance have been largely overlooked. Possibly much thinking that has been considered unconscious is really in the margin of our consciousness.

Jastrow says:

> There exists in all intellectual endeavor a period of incubation, a process in great part subconscious, a slow concealed maturing through absorption of a suitable problem. Schopenhauer calls it "unconscious rumination," a chewing over and over again of the cud of thought preparatory to its assimilation with our mental tissue.... The thesis implied by such terms has two aspects: first, that the process of assimilation may take place with suppressed consciousness; second, that the larger part of the influences that in the end determine our mental growth may be effective without direct exposure to the searching light of conscious life. Both principles enforce the view that we develop by living in an atmosphere congenial to the occupation that we seek to make our own....

Compare also Leuba, Carr, Tucker, and Brodie, who reach in general similar conclusions. (See bibliography appended.) Bancroft expresses this idea as follows:

> When we consider unconscious thinking we come into a field in which most of the psychologists are quite definitely on one side and most of the research men in other sciences equally definitely on the other side.
>
> It seems to be generally recognized that scientific ideas seem often to be an inspiration.
>
> Westaway has an interesting page on the intuitions of great minds.... "In science and mathematics, intuition is recognized as a legitimate mode of discovering truth....As to the fruitful hypotheses that have led so often to verifiable results in natural science, they seem to be almost of the nature of inspired guessing; truth seems to flash across the mind of the inquirer immersed in this research."
>
> Even when we make large allowance for the enthusiasm of biographers and writers of popular science, there can be no doubt about the suddenness with which ideas come.

Conditions for Successful Incubation

What are some of the conditions for helpful action of our minds when on the margin of consciousness and beyond?

First, we must have a great interest in the problem and a desire for its solution. This gives our minds the impulse to pursue this particular problem and assists in excluding other conflicting ideas. Furthermore, the problem should be clearly defined. "A question clearly stated is half answered."

Second, and closely allied, there should be an absence of other problems which would tend to crowd out the first. To paraphrase, "Where your treasure or your trouble is, there will your subconscious mind be also." No matter how diligently you apply your conscious thought to your work during office hours, if you are not really wrapped up in your work sufficiently to have your mind unconsciously revert to it at every opportunity, or if you have problems of so much more urgency that they crowd out the chemical problems then you can expect little in the way of a hunch.

Third, the mind must have available a large store of pertinent information. Just as looking up a question in a library, the larger the library, the more chance there is to find what is wanted. Poffenberger says:

> How shall we explain the great differences among people in their capacity to think and in the value of their thinking?
>
> One difference is in the *number* of suggestions that come to mind and in the varied relationships that are noted between the problem and previous experiences. A problem that would suggest to the mind of the genius many recollections and ideas would seem to the ordinary mind to have no connection whatever with the problem in hand. Such differences rest in part upon differences in natural curiosity which drives the individual to find out about things and look for relationships.
>
> Another difference has to do with the speed and facility with which the suggestions come—some too rapidly and some too slowly.
>
> The quality of suggestions which the mind offers may be a minor factor....

Fourth, the material should be stored in the mind in a systematic fashion and it should be well digested so as to be useful. A mass of isolated facts is as inefficient as a great pile of books without order or catalog. It is much better to have fewer facts well digested.

Billings has conducted an interesting experimental study into the relation between information and problem-solving ability. He found low correlations between scores made on the informational tests and the scores made on the problem-solving tests in the same subject. In some cases the correlation coefficient was nearly zero. Those who solved the problems knew the material, showing thus the necessity for information; but not all of those who knew the material could solve the problems, demonstrating the need for something more than mere facts.

Fifth, there must be a sense of well-being and a sense of freedom from interruptions. Woodworth says:

> We see in this experimentally studied case some of the conditions that favor invention. Good physical condition, freshness, mastery of the subject, striving for some result and "hopefulness." Now what is this last? Confidence, enterprise, willingness to take a chance, eagerness for action and readiness to break away from routine? Some of this independent manipulating spirit was probably there.

Benger in an excellent article on "The Organization of Industrial Research" states:

> Research work is more sensitive to the atmosphere surrounding it than most types of work.... I know of nothing that will inspire a man to do his best as much as expression of confidence in his ability to do his job.

Dimnet expresses the same thought.

Sixth, there should be an absence of other definite obstacles to the proper functioning of the mind.

Finally, there are certain types of direct positive stimuli to mental activity. These are usually some form of contact with other scientific minds. Reading an article describing scientific work along lines somewhat similar to our own will often start a whole train of thoughts connected with our own work. Equally beneficial in many cases is reading an article which presents a view to which we are opposed. The mind will become intensely active in searching more or less unconsciously for facts and arguments on the other side.

Better than reading is personal conference. As Saul Dushman said:

> In our laboratory we have no regular staff meetings. Usually the most successful staff meetings occur when somebody gets a hunch and talks to somebody else and gets a third man interested. By the time they get through talking to him, there may be quite a change in the original idea. We find it good to discuss things together at various times. There is no doubt of the value of laboratory discussions of problems.

To be of the greatest usefulness these laboratory discussions should be informal and small—limited to two or three. A spirit of helpfulness and mutual respect and confidence is essential. A spirit of distrust, or a very critical atmosphere will hamper the free flow of thought and the willingness of each one to contribute to the discussion his best thoughts as they occur to him under the stimulus of the discussion. At the same time those entering into the discussion should be worthy of the honor. Any one person can spoil the stimulating effect of the discussion by gross lack of the fundamental scientific background, by introducing flippant or irrelevant remarks or by distracting attention to himself at the expense of the problem. On the other hand, an appreciative listener, competent to understand the

ideas expressed, is the greatest possible stimulus to mental activity. With the more aggressive minds, arguments with one who takes an opposing view is a most powerful stimulant and will often bring out and clarify their own ideas. Compare R. L. Stevenson's "Memories and Portraits," "Talks and Talkers."

As a means of clarifying thought and compelling the organization of data nothing is superior to written progress reports, provided these are spaced at sufficient intervals, so that there is really something worth reporting. Reports at too frequent intervals are nothing more than mechanical summaries of data.

The head of the department of chemical engineering of a large university favors monthly *verbal* reports of progress. He says that the effort to describe the work verbally has a mentally stimulating effect not derived from a written report. Here again during the course of the creative work, we see the value of avoiding the caution inherent in the written word and the opportunity to give imagination fuller play. Occasionally the professor will ask a question which will bring out an entirely new point or will call attention to a fallacy. "Usually," he states, "I have to say very little. The benefit comes from the effort which the student himself makes to set forth his ideas clearly. He would derive almost as much benefit if he were explaining his work to a marble bust."

Ability to Grasp Ideas as They Appear

Closely related to the foregoing factors is the ability to recognize and grasp valuable new ideas as they flash before our consciousness. It will be remembered that Wallas follows Helmholtz in dividing research into investigation, incubation, illumination, and verification.

In the period of illumination, the original idea flashes before our consciousness. Two dangers are present: first, that the new idea or hunch may never appear before our consciousness; second, that its appearance may be so brief that we may fail to grasp it.

To allow for the appearance, periods of relaxation are necessary. Wallas cites the fact that A. R. Wallace "hit upon the theory of evolution by natural selection, in his berth during an attack of malarial fever at sea." When Einstein recently announced his profound generalization connecting space and time, he stated that the idea had occurred to him while sick in bed. Descartes made his discoveries lying in bed in the mornings.

Wallas states that sometimes we can feel the approach of a new idea before it arrives. This he terms a period of intimation just preceding the actual illumination. Whenever such a feeling occurs, we should use every possible precaution to encourage the appearance of the hunch. No positive action is possible. The most that we can do is to avoid embarking on any other train of conscious thought which may "start a new hare,"

as Wallas puts it, and so lead away from the hunch. It is at this stage that an interruption such as the telephone or a question by some other person is particularly disastrous. (See Hazlitt, Varendonck, and Graves as quoted by Wallas.) No laboratory would long tolerate a worker who consistently upset a train of apparatus elaborately set up by another. Yet this would often be less disastrous than to have a fellow worker with equal carelessness interrupting a promising train of thought, set up with great effort.

Hutchinson says:

> Inspirations are always to be captured at the fringe of consciousness, not at the focus; an evidence, perhaps, of their origin in the subconscious. To grasp them involves effort. All must watch for valuable ideas in the eddies and backwashes, not in the main current.

Many new ideas vanish as soon as they appear unless a particular effort is made to focus the attention on them long enough to fix them in the memory. A valuable device recommended by Hutchinson and others is writing down immediately any original ideas as they flash before us. A series of fragmentary notes of this kind can be turned to and worked over at leisure. See for example, Leonardo da Vinci's "Notes."

Value of Temporary Abandonment

It is admitted that after attacking a problem for some time without success, it is often well or even essential to abandon it for a time. This fact is mentioned by Carpenter.

In similar vein, Fehr reports that 75% of scientists investigated acknowledge the appearance of discoveries while engaged upon subjects foreign to their researches at the moment, while 90% often find it necessary to temporarily abandon important work.

The worker lacks that "flash of genius," mentioned by Davisson, which is so helpful to success. Under these conditions if further effort is abandoned for a time and then taken up again, it is often found that progress is made and a solution soon reached. "According to old Egyptian wisdom, 'the archer hitteth the mark partly by pulling, partly by letting go.'" (*Leuba*)

Some well-known scientists believe that the beneficial effect of temporary abandonment consists entirely in resting the mind, which later picks up the problem exactly where it left it. The situation, as they picture it, is analogous to that of a mountain climber. Exhausted by his efforts, he sits down to rest. After a period of rest he is no nearer the top than at the beginning, but is nevertheless able to make better progress simply because rested.

The benefits are probably more than mere rest and overcoming staleness. Carr says:

The nature of the hypothesis suggested by a given problem is to some extent a function of the character of the preceding train of thought. Baffling problems are sometimes readily solved after an interval of rest, this phenomenon is due in part to the fact that the problem is likely to be approached from a new intellectual standpoint. Some people have learned to take advantage of this fact in promoting their versatility of attack when dealing in different problems. In the event of continued failure, they abandon the problem for the time being, occupy their minds in the meantime in other intellectual pursuits and then return to its consideration with this new background of interests. It is sometimes alleged that a sense of humor.... is an aid to versatility. The importance of this mental trait can hardly be over estimated. It is the basic root of inventiveness and originality and it is usually regarded as one of the primal characteristics of genius.

Persistent Errors

The fact that the attack is seemingly unsuccessful shows that something is *wrong*. Sometimes merely more information is required. Often, however, the difficulty arises from an incorrect interpretation of the facts at hand. Having fallen into some error of interpretation, we fall into the same error every time we go over the facts. This often happens, for example, in adding up a column of figures. On leaving the problem alone for a while our mind "forgets" the temporary mistake in addition. So, in taking up any problem after a period of rest, we have the chance of leaving behind an erroneous point of view and of seizing upon one more fruitful.

Improvement after rest has been experimentally demonstrated in typing. Leuba says it is due "rather to the disappearance with lapse of time of numerous interfering associations, bad habits of attention incidentally acquired in the course of learning, interfering habits and tendencies which, as they faded, left the more firmly established typewriting associations free to act. Such hindering associations . . . form(ing) a serious impediment to progress." Similarly, "as we repeat the unprofitable thinking while exploring blind alleys, the production of the right thought becomes increasingly difficult."

Shaking off an important error in our course of reasoning can sometimes be achieved by going over the problem with another who approaches it without our preconceived ideas. There is a chance that his mind may be free from the error so fatal to our success in this particular case.

The following typical example of this is given by Cavanaugh. In certain parts of New York State there exist tracts of exceedingly rich land on which truck farming, especially lettuce raising, is carried out. On these tracts are certain sections on which the lettuce grows very poorly, in marked contrast to other sections. Cavanaugh investigated the cause of this failure to grow lettuce by making exhaustive soil analyses, searching for those elements in which the non-productive sections were deficient. All elements

believed to be of importance in lettuce growing were included. He compiled a mass of data without discovering the missing elements and intensive study brought him no nearer the solution of the problem. Finally, he explained his problem to a colleague. The latter took the data home one evening for further study and the next morning reported to Cavanaugh: "The answer to your problem is all in your data. The trouble with the non-productive soils is not that they lack anything, but that they are too rich in certain soluble salts." This, indeed, proved to be true. As long as the assumption of some deficiency held sway in Cavanaugh's mind, no amount of study would have revealed the answer. To another who really knew much less about the problem, but who approached it from a fresh point of view, the answer was at once evident.

Any one who examines the textbooks or even original scientific articles pertaining to that branch of science in which he claims to be expert, will discover a number of statements which he knows definitely to be false and will see many more that he strongly suspects are untrue. In our respective narrow fields of specialization, we know enough to read critically, rejecting much. Outside our own fields, on the other hand, we are apt to accept unquestioningly anything that we see printed in a reputable journal or textbook. Yet it is certainly reasonable to suppose that the bulk of scientific literature is just as full of errors as is that relatively small corner with which we chance to be acquainted.

No doubt many errors of fact enter into our thinking and form stumbling blocks to the successful solution of a problem. History records instances of very important problems which were attacked for a time without success because of some central assumption, commonly supposed to be beyond question, which later proved to be false.

So detrimental to success is this that several have made the following interesting suggestion: if a very important problem is to be attacked, it is sometimes worthwhile to assign two men to work independently. The first would make a preliminary study of the literature and attack the problem in the conventional way. The second man should be forbidden to read up on the problem and would thereby attack it from a fresh point of view free from the false assumptions of those who had so far failed in the solution of the problem.

To a certain extent a man is apt to be more original if he does not know too much about a given subject. It is particularly dangerous to read the records of too many experiments which yielded negative results. It seems that some laboratories even refuse to keep on permanent file records of such experiments and reasons why things cannot be done.

Hankin presents a most original and interesting discussion of the effect of knowing too much about a subject. Abel touches on the same idea when he says:

It is a curious thing in the history of science that many men.... have opened up new fields which.... went counter to existing knowledge and from many points of view were quite illogical and foolish in the opinion of men of wider experience.... Finally a discovery eventuated which a less daring, more experienced and in fact more logical individual would never have attempted. Here lies one of the secrets why young men with little previous experience, but with the imaginative faculty highly developed, and endowed with the qualities of dogged persistence, undaunted courage, and with the readiness to accept a new turn in the experiments, so often make very great discoveries quite early in life.

Importance of a Critical Attitude

A more practical policy than to develop the fear of knowing too much would seem to be to read everything which promises help, at the same time cultivating a critical attitude. A proper cultivation of the critical faculty is one of the greatest aids to originality and successful thinking.

We believe however that the benefits arising from the temporary abandonment of a problem are even more numerous than those just cited. We believe that an abandoned unsolved problem will remain in the mind as a challenge to its ability. Again and again, semi-consciously or unconsciously, the mind attacks the problem. When we finally take up the problem anew, the mind has made actual progress toward its solution. The complete solution may even appear in the form of a hunch. Many instances of this are recorded in existing literature and in the answers to our questionnaires.

Conclusion

Obviously the minds of different people work quite differently. In this paper we have given concrete illustrations from scientific literature and from specific answers of contemporary scientists showing how the minds of these investigators worked. We have pointed out some definite conditions which have proved to be favorable for creative mental achievement, and other conditions which are usually considered unfavorable. We have discussed some of the probable explanations.

From these facts and opinions—many of them conflicting—each must determine for himself what conditions are most favorable for his own creative mental achievement.

That some scientists will find the ideas here expressed anathema is certain. That many others will find in the foregoing pages some helpful suggestions is, however, possible.

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Another Oxide of Carbon. Carbon dioxide, CO_2, the product of the complete combustion of carbon, is an inert gas which has long been familiar to mankind in the foam of beer, the sparkle of champagne, and as the driving force of the soda siphon. More recently in its solidified form of "Dry Ice" it has extended its range of usefulness.

Carbon monoxide, CO, which results from the incomplete combustion of carbon, serves us well as a major constituent of ordinary illuminating gas and serves us badly in the exhaust gases of motor vehicles, which it renders highly poisonous by its habit of combining with the red coloring matter of the blood, which thereupon loses its power of uniting with oxygen in the lungs.

Familiar as both these oxides of carbon are to everybody, we now have to reckon with a third, the suboxide of carbon, C_3O_2, with which only a few chemists have as yet even a speaking acquaintance.

The suboxide is a gas at ordinary temperatures, but is easily condensed to a liquid boiling at 7°C. and to a solid which melts at about 110° below zero Centigrade. It has an unbearable odor like mustard oil; its dilute vapor brings copious tears. In greater concentration it attacks the whole respiratory system with suffocating effect. It burns in air to CO_2, and with water it forms malonic acid. With ammonia, aniline, and many other chemicals it unites to form a variety of compounds. Heated, it polymerizes to a dark red solid. Like many other laboratory curiosities it may one day find its place in industry.

These three oxides of carbon afford a striking illustration of the extraordinary difference in properties which compounds of the same two elements exhibit as the proportions of the two constituents vary. We have another example in the case of water, H_2O, and hydrogen peroxide, H_2O_2.—*Ind. Bull., Arthur D. Little, Inc.*

CHEMICAL EDUCATION, INDUSTRIAL CONTACT, AND RESEARCH IN THE ANTIOCH PROGRAM*

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The educational program of Antioch College emphasizes the broad features of a liberal education.

Under the coöperative plan students spend half-time at some practical employment.

There are, this year, 579 students employed on 318 jobs by 168 employers in 15 states.

Of this total, 37 jobs give employment to 70 students in work of a chemical or related character.

This technical work supplements the academic program and gives these students experience in their field of concentration.

Educational exhibits, literature, charts, slides, films, and lectures furnished by the industries supplement the academic work.

The improved facilities of a new science building have made possible an enlarged program of research.

Students, assisting on the several problems, receive training in the spirit and methods of research.

Introduction

The coöperative plan of education as applying to all departments of the Liberal Arts College was instituted at Antioch in 1931 at the time of the reorganization of the college by President Arthur E. Morgan. Under this plan the student body is divided into Division A and Division B; two students, one from each division, share a coöperative job in some industrial or commercial organization, and alternate on five, or (occasionally) ten-week shifts between the campus and the job. A few students, commonly about 50 out of a total enrolment of 650, are allowed, for special reasons, and for limited periods, to enrol as Division C, for continuous academic work, and these alternate in classes with the two major divisions. The presence on the campus of these Division C students has not affected the operations of the coöperative employment plan, as no special courses have been offered for them. However, plans are now being completed for the admission in 1931–32 of a limited number of freshmen into Division C, and special courses will be offered for them. This is planned to take care of the less mature freshmen and the privilege will extend only through the first year.

* Contribution to the symposium on "Coöperation between Industry and Chemical Education," held by the Division of Chemical Education at the 81st meeting of the American Chemical Society, at Indianapolis, Indiana, March 31, 1931. Presented under the title, "Coöperative Employment of Chemistry Students."

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REAR VIEW OF THE ANTIOCH SCIENCE BUILDING

This view shows the towers of the old Main Building and the wooded campus in the background.

Antioch a Liberal Arts College

In a paper prepared in 1925, Dr. C. S. Adams (*1*) described in some detail the features of the Antioch plan as it affects students in chemistry—particular attention being given in that paper to the cultural, or less technical, course in chemistry required of students not registering for scientific or technical courses. The coöperative plan frequently suggests to those unfamiliar with its working the idea of a technological institute, the coöperative jobs being looked upon as apprenticeships for future vocations. This is only a part of the real purpose of the plan. The Antioch program aims at the symmetry of a rounded cultural training, and this involves, even for technical students, such required courses as the social sciences, philosophy, and esthetics. Indeed, the cultural features of a liberal education are fundamentals in the Antioch program.

Extramural and Intramural Work Related

While the coöperative plan thus aims at a broad, liberal education, each student is assigned to a job for which he is best fitted and which best coordinates with his major academic studies, so far as this is possible. This allows nearly every student during the five- or six-year course to secure some practical experience in his field of concentration. A recent count showed 579 students doing coöperative work. There were 167 employers, not including the college itself, in 15 states. There was a total of 318 jobs—258 with outside employers, and 60 within the college organization. Of the total of 318 jobs held by Antioch students, 37 are in control or research laboratories, chemical manufacturing plants, sanitary districts, etc., and contribute directly and materially to the students' scientific, social, and economic education. Most of the jobs selected for purposes of this study

ANTIOCH'S NEW SCIENCE BUILDING, NORTH (FRONT) VIEW

This building, opened in September, 1930, was the gift of Mr. Charles F. Kettering.

are definitely "chemical." All of the 37 jobs are held by students whose college work includes technical courses in which chemistry is either the major or one of the minor fields of study, and in nearly every case the job itself has a definite chemical aspect. This will be evident from the following table which shows the names of the employers and the numbers and

TABLE I

Laboratory Positions Held by Antioch Coöperative Students with Commercial Concerns

Employer	*Number Students*	*Academic Year* 1	2	3	4	5	6
Bellevue Hospital, New York	4	2			2		
Bureau of Standards	4		2	2			
Cadillac Motor Company	2						2
The Carborundum Company	10	4	2	2	2		
Dayton Ohio Sanitary District	2			1			1
Indianapolis Sanitary District	4		2	1	1		
The Eli Lilly Company	2		1	1			
Mead Pulp and Paper Company	2		1	1			
National Supply Company	2				1	1	
Oxford Miami Paper Company	6		3	1	1	1	
Thresher Varnish Company	2	2					
Westinghouse Electric Mfg. Co.	6	2	2				2
Wright Aviation Field	7		1	1	3	2	
Beckett Paper Company	2		1	1			
	55						

TABLE II

Laboratory Positions Held by Antioch Coöperative Students in the Antioch Organization

Employer	*Number Students*	*Academic Year* 1	2	3	4	5	6
Bacteriology Laboratory	1						1
Biochemical Research	2			1	1		
Chemical Laboratories	4			3		1	
Geology Laboratories	2				1	1	
Hospital (research)	1	1					
Industrial Research	2	1					1
Physics Laboratory	2					1	1
Psychology	1					1	
	15						

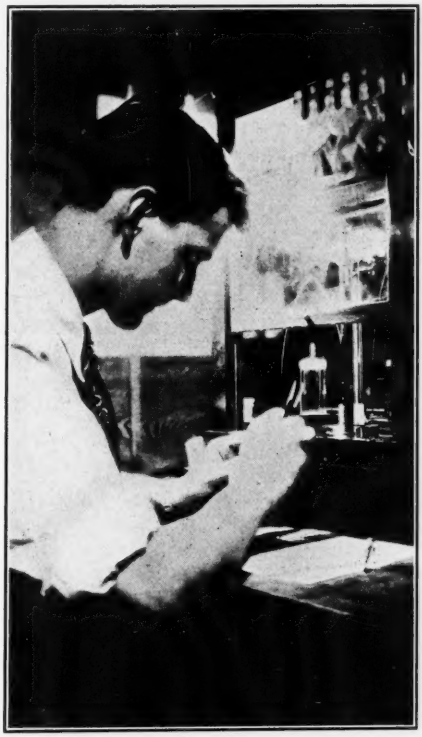
TABLE III

Summary of Laboratory Positions and Students Employed

Total jobs in commercial laboratories	28
Total number students in commercial laboratories	55
Total jobs in Antioch laboratories	9
Total number students in Antioch laboratories	15
Total number laboratory jobs	37
Total number students on jobs	70

academic ages of the students employed. Because of the nature of a few jobs, a student may have no alternate, as is indicated by the odd numbers in the second column of the tables.

The data presented in the table show the number of students employed on technical coöperative jobs at this time, and the mere names of the employers suggest the great variety of work done by the students. The table does not include a number of students who have held technical jobs in former years but are now enrolled as Division C students, or have transferred, for one reason or another, to a non-technical job. It will be noticed that only 10 freshmen are assigned to technical jobs. This fact reflects a natural requirement placed by the employer that the student come to the job with some training and capacity to accept responsibility, and it also indicates a recognition on the part of the employer of the value of academic training in meeting the requirements of the job. Indeed, the extramural school finds the coöperative jobs for the advanced students in the technical or engineering courses are the easiest to locate.



THIS SOPHOMORE RECEIVES VALUABLE LABORATORY TRAINING AT THE U. S. BUREAU OF STANDARDS, WASHINGTON, D. C.

Coöperative Work Has Educational Value

These coöperative jobs are readily evaluated in terms of chemical education. The lessons learned on the job require little emphasis in the classroom, and the attitude acquired is obvious in the students' approach to the academic problems. In turn, a general lecture or discussion is received by the student as representing some fundamental principle which perhaps he has failed to observe in his work, or as explaining the factors involved in an operation which he has performed but has not fully understood.

There is thus a supplementary relation between the coöperative job and the academic classroom or laboratory which cannot be fully realized by the student until late in his academic career. The student is "broken in" on a great many operations on the job before the principle involved is ever mentioned in any course. Thus, the importance and methods of sampling, standard solutions, Gooch crucibles, Kjeldahl nitrogen determinations, calorimetry, electrometric titrations, and the like, are commonplaces to many students before they take the course in quantitative analysis. Obviously, a satisfactory course in quantitative analysis for such students must be sufficiently flexible to allow the student to "cash in" on his cooperative training. The total effect is to broaden and lend variety to the course. A similar effect is obtained in other courses.

If we assume that the student, upon graduation, will find employment as a chemist in an industrial organization, then another phase of his training, more personal than chemical, is worthy of consideration. Every industrial chemist recognizes as a fine art the ability to secure the support of those above him and the coöperation of both those under his direction and those of the operating organization over whom he has only remote control. Until the graduate chemist acquires something of this art he is looked upon as an investment not yet fully productive. The coöperative students take pride in their accomplishment in this art of getting along with all classes of people in the world of affairs. Furthermore, no upper class coöperative student entertains any delusions about quickly rescuing his employer from the chaos of bad operating methods or saving him from economic disaster. The Antioch graduate has been initiated, and goes to his first full-time position with a balanced and rather mature attitude toward it and its possibilities.

The Students' View of the Job

Antioch students are typical of "modern youth," and express themselves freely and frankly. Realizing this, we recently secured from each of about 50 of the 70 students considered in this study a ten-line statement regarding his coöperative job and its educational value.

Let the students speak for themselves:

A freshman doing physical testing on an industrial research:

I have not found any direct connection between my job and school education.

A junior who had worked through the above freshman job to a more responsible position:

All the work done in college in the fields of physics and chemistry has been helpful in the various jobs I have had, and my contacts throughout the plant with men and bosses have been assisted by my study of Industrial Organization, Economics, etc.

Another freshman, being "broken in":

The work, as it is routine, is of little educational value in itself, but the contact with other people in the laboratory and the opportunity to learn something of their jobs make up for the deficiencies in mine.

A sophomore working with the United States Army Air Corps at Wright Field:

I intend to become an aeronautical engineer. This job gives me a remarkable opportunity to study all kinds of airplanes, and enables me to see how they are constructed. It is a very interesting job, and has none of the monotony so common in most factory jobs. It doesn't supplement my college work much, but I think it is a very good job.

A freshman in a pharmaceutical laboratory:

My work includes taking care of some of the animals used in the laboratory, making simple chemical solutions, and assisting in tests and operations on the animals. The work is a practical application of my Antioch training in biology and chemistry. In addition, I gain a general idea of the underlying theories of physiology and chemo-therapeutics.

A young woman student on an Antioch research project:

In my work at the Fels Foundation I do metabolism tests on women and children, in addition to doing urinalysis and blood chemistry. As my field of concentration is to be either biological chemistry, or perhaps medicine, this work is of material aid in my intended vocation, and my studies in the sciences give me greater insight into my work.

A freshman in the laboratory of a varnish manufacturer:

I believe I have learned more by first studying chemistry and then trying to apply it than if I had merely continued the studying. Perhaps I am fortunate in obtaining a position in which my employer is most anxious to have me learn this type of work. He is constantly plying me with reading material and encourages the asking of questions. . . . I once told my boss that I didn't know whether I learned more at college or on the job.

A sophomore in a paper mill laboratory:

When facts learned in school and facts learned on the job are correlated, the student has learned something not easily forgotten.

A sub-junior, after work on rubber, paper, textiles, leather, and sanitation:

In no case has my college work along any of the above lines preceded my work on the job. My usual procedure was to learn how to go through the motions of any determination that I was asked to do, then to learn the theory upon which it was based either upon my own initiative or later in school.

A sub-junior working with the Indianapolis Sanitary Commission:

My experience is invaluable to me as a method of acquiring good laboratory technic, learning something of the chemistry of sewage disposal, and as a kind of habit former which directs my ideas regularly and habitually along chemical lines and helps me to begin thinking in terms of chemistry as a result of my association with its applied phases.

A sub-junior, assistant on a biochemical research at Antioch:

It would be hard to find another "co-op" job which could be better suited to my present plans and my future aims than the one I now hold. I am a student assistant in the Photosynthesis Research, and my job is, in reality, a pure research job on a modest scale. Since I expect eventually to do research and teaching in biology, I am very lucky, indeed.

A junior enjoying a wide range of experience on sewage and sanitation:

I think that the two and a half years which I have given to this job have been well spent. I find that it is one thing to do laboratory work at school and the same thing plus a great deal more to do satisfactory work in a commercial laboratory.

A junior, after doing control work in a rayon plant and assisting in a college laboratory:

The chief value of my industrial and laboratory jobs has been to show me the gaps that exist between school-book theory and practical application in industry. My early job experience has given me a chance to see how I should attack my academic work and what elements of my college training will be most useful to me in life.

A sub-junior in the metallographic laboratory at Wright Aviation Field:

I look forward to the return to work after a period at school because of the great feeling of validity gained in working with men in the advance line of practical research. And after several weeks of work with newly developed materials and processes, I welcome the chance to return to the study of fundamentals.

A senior, assistant metallurgist with a motor car company:

The laboratory has an excellent library and we are encouraged to use it in order to understand the theory back of all we do. This work is in direct line with what I am studying at school and has proved the best sort of lab course possible, inasmuch as the equipment is very complete and I can spend enough time at it to receive some real benefit from the work.

Another senior in the same metallurgical laboratory:

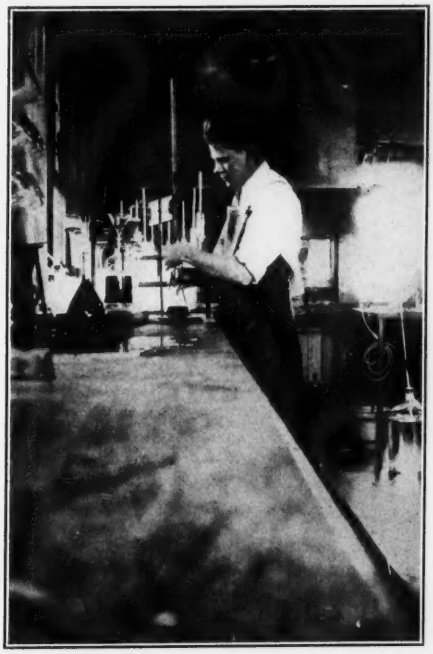
It presupposes an elementary knowledge of metallography which necessitates being in school a few years before being competent for the job. Being a senior, it is exactly the work I have wanted. My college training has been most helpful, not entirely in a technical way, but it enabled me to discover my life's work and the job for which I am best fitted.

A senior with the Dayton, Ohio, Sanitary District has his career definitely planned:

I consider that my college work is supplementary to my job. It has given me a mixture of chemistry with bacteriology that better fits me for the work I want to do.

Another senior comments:

In my rather varied industrial experience I have had contact with such technical problems as sewage processing and a host of pathological and physiological problems in the Federal Bureau of Plant Industry. From these jobs I have learned the methods of attacking an original research problem, something which an undergraduate rarely gets in school. I have had to do work which would satisfy myself instead of the instructor. This often meant the checking and rechecking of a result, something seldom done in rushing through a course. I have come to regard the college laboratory as a place to learn to use tools. On my research job, I learn how these tools are applied.



A JUNIOR ON DUTY IN THE LABORATORY OF THE SANITARY DISTRICT OF INDIANAPOLIS, INDIANA

These statements reflect very accurately the view the students take of their coöperative jobs, and the enthusiasm with which they grasp the educational values offered.

A Balanced Training

For a decade Antioch has been sending students into the industries. Both the college and the students have been pleased with the educational value received. This value comes, of necessity, in a specialized and different form to each individual student, and might be criticized as representing premature specialization. The program is justified when it is shown that the student gains these advantages in his field of concentration with no corresponding loss of balance in his program of liberal education. It has already been mentioned that the requirements at Antioch for a balanced program are possibly more rigid than at the average liberal arts college. Confining this discussion to chemical education, the Antioch program

THIS SENIOR HOLDS A RESPONSIBLE PLACE IN THE CONTROL LABORATORY OF THE OXFORD MIAMI PAPER COMPANY, WEST CARROLLTON, OHIO

offers the usual undergraduate courses in general chemistry, technical and cultural, qualitative and quantitative analysis, two years of organic chemistry, household chemistry, inorganic preparations, two years of physical chemistry, industrial chemistry, a year each of metallurgy and metallography, and various seminars. Since students majoring in chemistry usually elect more of these courses than the required minimum, it may be said that a student graduating with chemistry as a major, receives a balanced training both with respect to the field of concentration and the college course as a whole.

Educational Exhibits and Literature

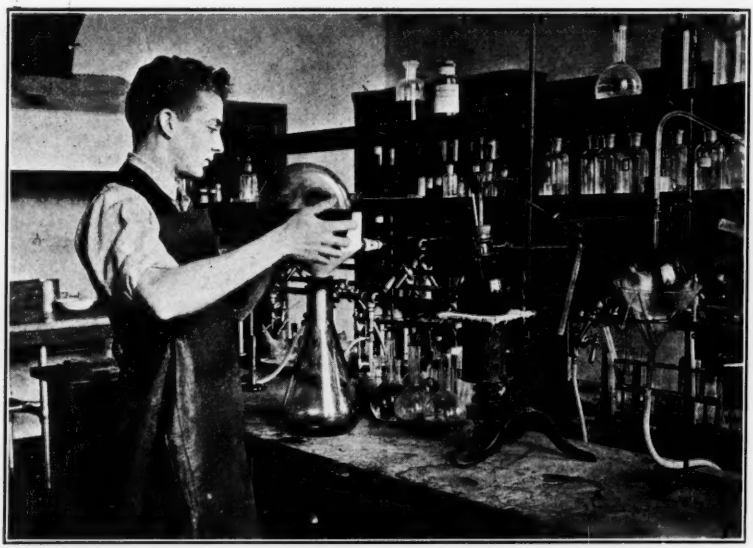
Whereas our technical students have gone into the industries and have received specialized training, it has recently become possible to invite the industries into the lecture rooms and corridors for the general education of all students. The splendid new science building which was opened in September, 1930, offered the necessary space, and the industries are being invited to place in this building their educational exhibits and literature. To date more than fifty companies, representing a wide range of chemical and engineering industries have supplied an excellent collection of educational material. This material is used regularly in the courses in general and industrial chemistry with most gratifying effect. The importance of visual education needs no defense. The student tires of the black and white illustrations of the usual chemistry textbook. Small wonder, then, that the average chemistry student, after reading the plain facts of the text, feels his interest rise when he is handed an attractive, well-illustrated manufacturer's booklet, or shown an actual collection of the materials being studied. Witness the agreeable surprise the student manifests when, after reading the chapter on silicon with its usual sorry photograph of car-

A FUTURE ENGINEER STUDIES AERODYNAMICS AT WRIGHT FIELD, DAYTON, OHIO

borundum, he sees an actual sample of that compound. Thus, bringing the arts and industries into the academic halls in the form of sample exhibits, illustrated booklets, flow sheets, charts, lantern slides, films, and occasional lectures by industrialists vitalizes the work for the technical student and gives to the general, or cultural, student a more vivid and, we submit, a truer conception of the place of chemistry in modern civilization.

Research at Antioch

In a recent paper, Professor J. O. Hertzler (*2*) of the University of Nebraska, states: "Our colleges and universities are grievously failing to meet one of their greatest obligations if they do not give their students, and through them, the population at large, the research spirit." It must be said that there is a growing tendency in undergraduate education to accept this challenge. Reorganization of curricula is under way in many schools. Adjustments such as those being made in the University of Chicago (*3*), experiments like that going on at the University of Wisconsin (*4*), the Swarthmore plan of honors courses (*5*), the venture being made at Rollins College (*6*), the innovations in the Antioch program (*7*) all point to an emphasis on student interest and to an enlarged freedom on the part



A COÖPERATIVE ASSISTANT IN THE PHOTOSYNTHESIS RESEARCH LABORATORY AT ANTIOCH

of the student in the selection and pursuit of subject matter. Autonomous courses have been offered at Antioch for nearly a decade, and it was inevitable that the pioneering plan of the new Antioch should gradually be enlarged to include some major undertakings in the fields of pure and applied research. The new building with its excellent facilities, has made possible this year some very decided steps in this direction. The Antioch Industrial Research Institute has been incorporated as a legal device for handling the endowments and funds for certain research projects. The work of the Institute is under the direction of Dr. C. S. Adams. The major projects under study at present may be mentioned:

The Fels Research, begun in 1929, is a project endowed for the study of the effects of prenatal and postnatal environment on human beings. This investigation is directed by Dr. L. W. Sontag, of the department of Health and Physical Education, assisted by the departments of biology and psychology.

The casting of art bronze is the subject of another study of several years standing. A special laboratory is equipped for this work, and a recent Antioch graduate is employed full time under the direction of the Research Institute.

The Desert Plant Research concerns itself with substances found in desert plants. Dr. J. W. H. Aldred, of the department of chemistry, accompanied by a recent graduate and a freshman, spent the summer of

1930 collecting information and materials in the southwestern states, and at present is making laboratory studies of the extraction products.

An important research on the economic reduction of an ore, financed by a private corporation, is being conducted, under the direction of the Institute, by Dr. S. J. Broderick and Dr. Earl H. Brown of the departments of metallurgy and physical chemistry.

A ten-year study of photosynthesis has been made possible by Mr. Charles F. Kettering. This work is under the direction of Dr. O. L. Inman of the department of biology, who is assisted by Dr. V. M. Albers and Dr. H. B. Knorr of the department of physics, and by Dr. Paul Rothemund. Dr. Rothemund has recently come to Antioch from the laboratories of the Technische Hochschule, of Munich, where he worked with Hans Fischer who received the Nobel prize in chemistry in 1930 for his work on the synthesis of hemin, and with whom Dr. Rothemund had become interested in photosynthesis. Dr. Inman had been interested in photosynthesis for some years.

Other researches are being conducted on the Antioch campus; those mentioned here are the projects that are of a chemical or biochemical nature. A number of these projects employ students on the full-time cooperative basis; others employ Division C students for part-time work. All these researches are carried on, as it were, before the eyes of the whole student body. Antioch students and instructors come into intimate contact, and the research projects are common topics of campus discussion. All students are encouraged to develop the inquiring attitude, and through the autonomous plan of study and the problems presented, the advanced student has ample opportunity to acquire and exercise the spirit of research.

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Failures result much more frequently from lack of knowledge than from wrong decisions when facts are available.—ALFRED P. SLOAN, JR.

CHEMICAL INDUSTRY AND THE CURRICULUM*

ALFRED H. WHITE, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN

A student's general training should fit him to think accurately and express himself clearly. His professional training should be directed toward a specific sphere of usefulness. Thirty years ago ability to make analyses was the most important end. Now most routine analyses are made by untrained analysts. Until rather recent years the chemist attempted from his laboratory to supervise plant operations actually directed by superintendents who were not chemically trained. Now plant operations are directed by superintendents who understand the theory of the process as well as the technic of factory operation. The plant laboratory is no longer a goal. The worthwhile fields are in research, development, and operation. All of these fields demand an ability to apply general laws to new conditions. Mathematics and physics should be emphasized and special attention placed on the formulation of problems. Laboratory work in chemistry should be restricted, and principles and problems stressed.

. . . . . .

Thirty years ago the American Chemical Society celebrated the twenty-fifth anniversary of its foundation, and in that same year William McMurtrie delivered his presidential address to that organization on the subject, "The Condition, Prospects, and Future Educational Demands of the Chemical Industries," from which the following paragraphs are quoted:

> So then we find that the chemical industries of the United States are growing with enormous rapidity; that they are being concentrated into fewer but larger works; that operations and reactions are being carried out with a magnitude which the earlier chemists would never have predicted; that new methods are being followed; new principles applied, greater accuracy of results demanded both as to quality and yield of the products; that the products now issue from the works in lots of tons at a time of a higher degree of purity and with a greater economy than was possible but a few years ago with lots of a few hundred pounds.
>
> And if so great advance has been made during the closing quarter century and even decade, what shall we say of the possibilities of the future? What is to be the magnitude of the chemical industries of the United States? What shall be the character of the products issuing from them? What will they require of the men who must direct and control them? That is to say, what will be the educational requirements of the American chemical industries of the almost immediate future?

These words from an address delivered a generation ago may be applied without change to our present situation. The growth of the chemical industry and the improvements in quality of products as well as scale of operation have surpassed even the wildest expectations of Dr. McMurtrie's generation, but his queries as to the future demands of the industrial world still call for our most careful consideration.

* Contribution to the symposium on "Coöperation between Industry and Chemical Education," held under the auspices of the Division of Chemical Education at the 81st meeting of the A. C. S. at Indianapolis, Indiana, March 31, 1931.

At the time of the delivery of his address the American Chemical Society had a membership of 1750 and it was estimated that there were 5000 chemists in the United States, of whom eighty per cent were connected with industry. Now the American Chemical Society enrols ten times as many members as thirty years ago. Statistics are lacking as to the total number of chemists in our country at the present time, and no accurate census would be possible without agreement on the definition of a chemist. It is certain however that, if we exclude retail pharmacists and physicians as more properly belonging in a different category, the chemical industry still employs most of those who have any right to the name of chemist. Those who were preparing to become professional chemists a generation ago expected as a matter of course to enter the laboratory of some plant and perform the analyses needed to permit the process to function in its normal manner. Now analytical chemistry is standardized and methods of analysis are well worked out. Standard samples are available so that the analyst may check the accuracy of his work. A few skilled chemists are needed in large plant laboratories to handle the unusual analyses and to act as supervisors, but most of the analytical work is done by assistants who work accurately and rapidly without having proceeded farther in their formal training than the high school. Some of these young men and women educate themselves to become real chemists. Most of them remain merely skilled workmen. There is a demand for a large number of such routine analysts, and whether we like it or not, they are called chemists. So also there is a real field for young men who have completed their high-school course and also pursued a further and, usually, highly technical curriculum of two years' duration designed to give them specific training for a particular industry as well as some grasp of fundamental principles. I am not, in this paper, discussing such a curriculum but considering only the program of a four-year college course designed to train men for professional service in chemical industry.

Has the curriculum in chemistry in our colleges changed with the change in emphasis in the industrial world? There have been profound changes in our theories. When I was a student I was taught that an excess of a reagent meant one molecule more than the theoretical amount. So also we were firmly convinced that atoms were little round balls stuck on wires which might be built up into curious structures. Mathematics and chemistry were strangers. A commonly accepted conception of physics was that it dealt with changes in particles of matter larger than the molecule. The molecule and the atom belonged in the domain of chemistry. Then physics played a mean trick on chemistry by vaulting over the molecule and atom, and by exploring the space within the atom gave us an entirely new viewpoint of the structure of matter. Physical chemistry has come into being since my day as a student and the laws of equilibrium and mass

action permeate or at least should permeate, all of our courses. Synthesis of carbon compounds and a study of structure has replaced the study of methods of proximate analysis which formed an important part of the curriculum when I studied organic chemistry.

A college curriculum may be sub-divided in various ways at the whim of the investigator. One method is to divide the courses into those which are strictly professional and those which are general. The general courses should give a student training in scientific method, the ability to think clearly, and to express himself well, and a general background of knowledge which will prevent him from being grossly ignorant when discussing non-professional subjects. The professional courses include those subjects which give specific training for a chosen career.

A college is a good deal like a factory which receives, as its raw material, forgings already partially fabricated and which further shapes and refines these bits of metal and then hands them over to a purchaser who fits them into his own machine. The college must turn out a marketable product or it will fail just as any other manufacturer will fail under similar conditions. One of the first questions to be settled in considering the curriculum which should be adopted in training men for the chemical industry is the use to which the manufacturer is going to put the college graduate.

I have already alluded to the fact that the college graduate formerly looked forward to a career in the analytical laboratory and that the situation has changed. The routine analytical laboratory may frequently be the place where college graduates commence their industrial work, and where those who lack energy and initiative find themselves permanently stranded, but it is not a field to which graduates should aspire.

The desirable fields for young men with chemical training are in the research, development, or process divisions. For the research division, graduate training is almost imperative. Research workers must not only be prepared to work accurately and intelligently, but to generalize from a mass of specific experiments, and extract therefrom the general law. The workers in this field must, of course, be trained in the various divisions of chemistry but they must also possess a thorough knowledge of physics and mathematics.

The development division has been established in rather recent years to translate the results of the research laboratory into the practice of plant operation. Men in this division must know the methods of forcing chemical reactions to take desired paths and the feasibility of the various methods which are theoretically possible. They must not only be able to calculate the amount of heat to be absorbed or removed from a reaction, and the changes due to temperature and pressure, but must also know how to maintain desired conditions and economical operation on a manufacturing scale. They must know the properties of materials and be able to

balance cost against efficiency. Most chemical processes may be divided into a rather small number of operations largely physical in nature which are called unit operations. Such subjects as heat transfer, filtration, evaporation, and crushing are instances of these unit operations. Courses in these subjects have been developed during the last ten years and are now well established. Those who aspire to enter the development division should be familiar with this field.

The advent of chemically trained men into the control of the manufacturing process is also rather recent. In the older days the chemist sat in his laboratory and told the plant superintendent when something was wrong. The plant superintendent probably did not understand the problem and did not know what to do about it, but resented advice from an outsider. There was almost necessarily lack of coöperation. When chemically trained men were placed in the factory as operatives or foremen, they were in a position to understand the plant superintendent's difficulties as well as the chemist's viewpoint, and as these men later were promoted to be themselves superintendents there came a better coördination of the plant and the laboratory. The modern superintendent is no longer dependent upon the advice of the laboratory chemist for he is capable of supplying his own interpretation of the analytical data submitted to him. The control laboratory has therefore become a service laboratory and lost its status as a directing institution. It is hardly necessary to say that the student who is preparing for an operating position needs not only chemistry and physics but also considerable training in the methods of conducting operations on the manufacturing scale.

When a graduate leaves college and enters industrial work in any of its divisions his first success usually comes from his ability to do something which the men around him could not do. The student's ability to use his information should be constantly stressed. It is not enough to memorize principles and demonstrations. A student must be able not only to obtain and record data, but also to analyze and generalize from them. The formulation and solution of problems should be an important part of every single course in chemistry, mathematics, and physics. The program which is indicated for a student ambitious to rise in chemical industrial work is one which includes mathematics through calculus, with emphasis upon the ability to formulate problems as well as to carry through the mathematical operation. This calls for coöperation on the part of the mathematics teacher. In physics also emphasis should be placed on problems. The time devoted to mathematics and physics together should be as much as that devoted to chemistry.

The work in chemistry should be devoted to an understanding of principles as evidenced by the ability to solve problems. Laboratory work should be restricted. Exercises should be chosen which illustrate prin-

ciples and which develop habits of accuracy. Qualitative analysis is, in itself, unimportant. Quantitative analysis is valuable but has in the past been overdone. The amount of attention given to organic chemistry may well vary with the major interest of the student. Physical chemistry should pervade all of the courses. The courses in physical chemistry proper should be taught rigidly and from a mathematical standpoint. Too much attention has often been paid to dilute solutions. The chemical industries are seeking to force reactions into definite paths, and a study of equilibrium and the methods of displacing it is of prime importance.

The aim of a college curriculum should be to prepare the graduate to progress in his chosen field. Stress should therefore be placed on those subjects which he is not likely to master by individual reading or study after he becomes engaged in practical work. He is not likely to undertake a study of a new subject, particularly if it is mathematical in nature. He will, however, pursue with relative ease new developments in a subject with whose fundamentals he is familiar. The three subjects of mathematics, physics, and chemistry should constitute the backbone of the course. English, languages, and economics offer a relief from the strictly scientific work and have a professional as well as a general value. The complete solution of any manufacturing problem involves an economic factor which cannot be taught adequately in college. Courses of study intended to train young men for industry should contain the elements of economics and accounting, for although corporations are organized ostensibly to make a wide variety of things, they are all organized actually to make only one thing and that is money. It is a mistake, however, to lay too much emphasis on courses in economics and business administration. A student who expects to rise in his profession must keep studying constantly after leaving college. He will not have much need of business administration during the early years of his professional life. Books on business methods are plentiful and should offer no terrors to the student whose mind has been developed by a rigorous course in scientific study. The ambitious young man will obtain a knowledge of finance, sales, and other important subjects in advance of the time when he needs them, through correspondence schools or through private study. French and German are less important than a generation ago because much more of the research work of the world is published in English than was formerly the case, and because *Chemical Abstracts* brings the most important information from the foreign journals. However, any one who aspires to graduate study, or research or development work should acquire a foundation in these two languages, upon which he may build through his individual study.

The preceding sections of this paper have discussed the subjects which should, in the author's opinion, be contained in any course of study fitting men for chemical industry. The man who expects to remain in the research

laboratory may succeed without much knowledge of the materials used in the plant or the methods of securing efficient and economical results on the large scale. The number of men who are employed in laboratory research is and probably will continue to be a small fraction of the chemists who are connected with manufacturing operations. The student who is not strongly attracted to the research laboratory and who thinks his interests will lie in development or operation rather than the laboratory, should certainly study the unit operations which underlie the various chemical processes, and their applications to industrial work. He should also have some knowledge of power and its utilization in machines. This is a heavy program and should apparently call for more than four years of preparation. It might seem that the technical courses should be restricted to a fifth year, but the trend is distinctly against it. The student enjoys the work more and absorbs it better if the applications are taught at about the same time as the theory.

In planning a curriculum for men who are to be trained for active participation in industrial work I would divide the course into five ribbons which would, within practical limitations, continue through the whole four years and have equal width. These ribbons would be first, English, languages, and economics; second, mathematics and physics; third, chemistry; fourth, chemical engineering; and fifth, other engineering. A student with that foundation who wished to go forward into graduate work with major emphasis upon chemistry as a science rather than upon its applications could build upon it with certainty and would be of more value as a research chemist because of his ability to understand the problems of the men who would be expected to translate his discoveries into practice. His path would not be blocked if he desired later to transfer his activities to plant operation. Students who have had superior records in such a curriculum as undergraduates and who have received graduate training and preferably progressed to their doctorate are being eagerly sought by industry and paid attractive salaries. The way is clear for them to progress by their own efforts along whatever line seems to them most desirable and promising.

The representatives of the larger corporations who come to our schools seeking desirable recruits lay much stress on ability, energy, and character in an applicant. They state that they can use a superior man no matter what his training has been. That does not, however, give us who are teachers an excuse for failing to recognize that we may greatly help or greatly hinder the student in his future career by the course of study and the way it is taught.

The curriculum is more than a collection of courses. It is a source of development, and should be of inspiration, directed by an enthusiastic and well-trained teacher. No curriculum can succeed if the teaching staff

does not keep in view the purpose of the whole program and is not willing to subordinate individual ideas to the general plan. And no teacher of chemistry can be a success if he does not understand the value of mathematics and physics as well as chemistry. If there are still schools requiring or permitting undergraduate or graduate students to continue taking course after course in chemistry without keeping a balance with mathematics and physics, they need not be surprised at the resentment of their graduates who find progress blocked by the narrowness of their preparation.

X-Rays at Work. Atoms and molecules, the minute particles of which all matter in the universe is believed to be fundamentally composed, are being deprived of the privacy which has heretofore surrounded them. Scientific investigators are now permitted to study substances whose structure previously has been a mere matter of speculation or guesswork. Characteristics and arrangements of these ultra-minute units may now be determined with comparative facility by means of the X-ray.

This type of work, commonly known as X-ray diffraction study, should not be confused with the radiographic procedure which is used to differentiate between materials of different densities. For example, radiography is used to observe or detect such conditions as flaws in castings and other non-uniformity within an opaque substance. Such a method is relatively gross as compared with diffraction investigations.

X-ray diffraction work may be defined as the study and measurement of the interference rings produced when X-rays passing through a substance are diffracted by the atoms. It will be understood that when the X-ray passes through a material and encounters atoms, diffraction occurs, causing the formation of diffraction patterns which are recorded upon suitable photographic film.

X-ray diffraction methods have reached the point of development where they assume commercial and practical value, providing the research chemist or engineer with a new means of observing structure and arrangement in practically any molecular system. Not only is it possible to determine the normal structure in a given substance, but the X-ray assists in bringing about a rearrangement of the natural structure to impart to any given substance new properties which may prove desirable.

Industrially, the application of X-ray diffraction study is in its infancy, but, due to its remarkable potentialities, promises to become an important factor in future scientific developments.

Rayon, rubber, metal, and in fact practically any substance having definite molecular arrangement can be successfully examined by X-ray methods.

Perhaps one of the outstanding accomplishments attributed in part, at least, to the X-ray diffraction studies has been the improvement effected in artificial silk. One of the most undesirable properties of rayon, as formerly produced, was its inherently slight tensile strength when wet. A study of its properties and examination of the structure of this most remarkable material resulted eventually in a rearrangement of the molecules, and the final commercial success of this research is attested to by the almost universal adoption of rayon as a standard fabric, ranking with silk, wool, and cotton.

Rayon is but one of many substances to which X-ray study is applicable, and in many research lines, such as rubber and metal investigations, it has been proved of definite assistance. The future holds many important problems for X-ray investigations, and it is most probable that many substances will have their desirable properties accentuated, and their undesirable ones eliminated, through the improvements made possible by the information furnished by X-ray studies.—*Ind. Bull., Arthur D. Little, Inc.*

TRAINING CHEMISTS IN INDUSTRY*

H. W. Elley, Dyestuffs Department, E. I. du Pont de Nemours & Co., Wilmington, Delaware

Stress is laid on the importance of chemists obtaining a thorough grounding in the fundamentals of chemistry during their collegiate years and it is not expected that they should be versed in any particular branch of applied chemistry when they enter the field of applied chemistry.

The advantage of post-graduate study is outlined and it is shown why chemists are able to progress more rapidly with this type of training than the usual four-year course. It is pointed out, however, that some of the most capable industrial chemists are those who have not obtained advanced degrees and it is emphasized that ultimately the four- or five-year chemist has as great opportunity as the Ph.D.

The organization and methods of one of the departments of the du Pont Company is used as an illustration for outlining concretely the conditions confronting a chemist entering the field of applied chemistry and the phases of his progress in such an organization are described in some detail.

The analytical approach to research problems is discussed and it is shown why this method has yielded outstanding results.

The classification of research effort into various categories is outlined and the distribution of effort between research and plant laboratories is described. The method of training chemists in research work of highly technical nature is illustrated and emphasis is laid on that type of experimental activity which is aimed at confirming a carefully thought-out idea rather than the accumulation of a large amount of data from which it is hoped it will be possible to get an idea.

The various types of personality found in research chemists are commented upon and it is brought out that the steady, dependable, systematic individual is quite as indispensable to a well-balanced organization as is the brilliant, temperamental, inventive, genius type.

The requirements of an operating chemist are given and it is made clear that the broadest possible training is essential in order that the maximum efficiency and lowest costs be obtained. A unique combination of technical skill, business ability, and appreciation of human relationships is required.

. . . . . .

Probably it is not as true now, as it was formerly, that a chemist completing his collegiate training is quite unfamiliar with industrial conditions I recall my own experiences quite some time ago, when I had completed my college work, and certainly my idea of industry was very vague. The chemical departments of universities were not besieged by industrial personnel men who wished to tell the prospective graduate about industry in general and their companies in particular. However, we are concerned with the

* Delivered as part of the students' course in Industrial Chemistry held at the 13th Exposition of Chemical Industries, New York City, May, 1931.

present and future and it is undoubtedly true that nowadays the chemist has many opportunities for contacting industry and knows something about it. It is still true, however, that there is practically no possibility of his spending sufficient time, during his college work, to become very familiar with any branch of applied chemistry. Neither can he know, in detail, about the internal workings of a manufacturing enterprise. The exception to this is, of course, with those colleges that give coöperative courses in which the chemist or engineer spends part time in some industrial plant.

We find that properly chosen men, when they come to us, have very good grounding in the fundamentals of chemistry and also have those personal characteristics which should enable them to work effiicently and harmoniously with their fellow chemists and those directing the work. The necessity of intimate familiarity with the basic fundamental facts of chemistry cannot be over-emphasized. Chemistry is entirely concerned with the multitudinous combinations of matter and although new compounds are found to be unique in their properties yet it is only an average or a consolidation of the properties of the constituent parts in that particular configuration. Something can be guessed or foretold of the possibilities inherent in a compound if the properties and reactive capabilities of the component groups are known. This basic information is the foundation material of chemical building. How can progress be made if the specifications of the building materials are unknown? The architect does not have any conception of the individual projects he will be called upon to design when he is studying, but he does know that by proper preparation he can combine design and materials to create anything which man can reasonably conceive. The same is true in chemistry. The task confronting the employer, therefore, is to so guide the newcomer's activities that in the shortest possible time he will become familiar with the detailed subject matter and with the objectives of the organization and be able to carry on independent work efficiently.

In general, there are two types of chemists who come to us. The first is represented by the four- and five-year men and the second by those who have pursued their post-graduate studies for several years and have received their doctor's degrees. There has been much discussion in regard to the necessity for Ph.D. training in order that a chemist might be eligible for the greatest advancement. Experience shows that it is not essential but that it helps greatly—particularly from the standpoint of speed of advancement. In most companies the Ph.D. is placed in research work immediately and he starts out at a salary substantially higher than the four-year man. Moreover, there seems to be a more or less subconscious tendency to advance the Ph.D. more rapidly to positions of greater responsibility. However, it should be pointed out that some of our most productive, capable, and important men do not have advanced degrees and

this proves that the higher degree is not a prerequisite to advancement and that, in the final analysis, progress depends on the man and what he is able to deliver in the way of accomplishment. It is an open question as to how much farther or faster a four-year man would have gone if he had started out with an advanced degree. In *either* case, it is necessary to give him additional training to enable him to carry on research work in the laboratory or to participate in the manufacturing operations. The training depends on the extent of the collegiate work and the type of activity which the individual seems best adapted to or for which he has a predilection.

If you wish to take the Dyestuffs Department of the du Pont Company as an example of the methods employed in training chemists, I can tell you what the conditions are and what happens to a newly arrived chemist. It is of interest to note that all of the chemists are originally located in the research laboratory and gain their first experience in this section of the Department. The research laboratory is composed of a group of Divisions each having from ten to thirty chemists and corresponding to the natural classifications of the work being carried on. In this laboratory we have seven Divisions, some of which have component sections. Each Division is directed by an experienced chemist of considerable maturity and background. In fact, any of the Division Heads would be qualified to carry on independently and because of the size of their staff and the diversity and complexity of the work they direct, their Divisions are really comparable to independent research laboratories.

In one of the research divisions there is placed the central analytical laboratory of the Department. The analytical laboratory has various lines of activity, one dealing with the analysis of raw materials, from which official specifications are set up; another with the analysis of control samples from the manufacturing processes as a check on similar analyses carried out by the plant laboratories; another analyzes samples which are the result of research investigations while still another is concerned with the development of new and more accurate methods of analysis. It is evident, therefore, that in this section it might be said that it is possible to get a cross-section of the entire activities of the Department. Because of the fact that the four- and five-year chemist has had little or no experience in conducting research investigations and would consequently be under a considerable handicap in that type of work, it has been found very advantageous to him to be placed in the analytical section when he is starting out. He already knows something of the technic required and he has an opportunity to add to his fund of knowledge in a normal manner. As soon as he has mastered one determination he is given a new one. He is urged to inquire into the source of the sample he analyzes; and to get a description of the process from which it came; to study the technical literature pertaining to the subject; to discuss it with the chemist submitting the sample

and thus gradually to become versed in the art. In order that the new chemist may see a little farther than the horizon of the analytical laboratory he is taken on scheduled visits to the various manufacturing areas and under the guidance of the plant supervisor or superintendent the operations being carried on are explained to him in as much detail as he would be expected to appreciate. In this way he obtains a very concrete idea of what is going on and is able to see an application of some of his laboratory experience in terms of tons of material and to get an ultimate visualization of the profits on which industrial companies are established. His work becomes more real to him and he attacks the daily work with increased enthusiasm.

As his experience grows, he is given problems which tie in very directly and intimately with research problems or manufacturing operations. If the purity of a product is low, he is asked to identify and estimate the nature and amount of the impurities present in order that an idea may be gained of the side reactions which are going on. An appreciation of this sort and a knowledge of the conditions under which these compounds could be formed will many times suggest a modification of procedure which will result in substantial increases in yield of the desired product. The application of analytical methods and technic to synthetic reactions frequently results in improvement in synthetic work.

Another most important phase of the analyst's work is in the development of control methods by the use of which the progress of a reaction can be followed or the purity of the final product can be accurately determined. The working out of such methods requires absolute familiarity with the chemistry involved in the particular synthesis under consideration as well as a broad knowledge of chemistry in general so that reactions may be employed which will be effective in solving the immediate problem. I venture to say that a chemist who is required to work out a wide variety of control methods must know more chemistry than chemists whose duty it is to synthesize new compounds in a highly specialized field. And it should be pointed out that without adequate chemical control, and this means accurate analytical methods, progress is bound to be slow and very uncertain. During this period the chemist has an opportunity to find himself and to form a better idea of whether or not the industrial environment really appeals to him. He is thrown into contact with many people who have been in industry for many years and whose opinions are to be valued. He can see in the accomplishments and positions of others what is potentially ahead of him. It will be a test of his patience and also his faith in himself, and this is an essential part of his training.

On the other hand, it offers those in charge of the work an opportunity to size him up and to determine what sort of a person he is and what his capabilities seem to be. It will be determined to what degree he has the ability and desire to apply himself, how ingenious he is, and the extent to

which he is able to coöperate with those around him. In the course of a few months it will be evident whether he is able to go ahead or whether his chances of advancement are poor and a change would be desirable. His work in this section lasts for varying periods of time, depending on the rate of his development and on the requirement for men in other lines of work which I will describe.

The work of the research divisions is classified under various categories such as (*a*) control of going processes, (*b*) improvement of going processes, (*c*) additions to present lines, (*d*) new ventures, and lastly (*e*) fundamental research in pure or applied chemistry. The percentage of the total research force delegated to these categories varies, but in general comparatively little work is carried out in categories (*a*) and (*b*); a predominant amount in (*c*); an increasing amount in (*d*); and only a moderate amount in (*e*). Since the majority of the work of the research divisions is of a purely developmental nature, requiring expert technic and extensive background of experience, it is obvious that it is essential to have it carried out either by or under the immediate direction of the older men. In order to replace those who drop out or to make it possible to increase the volume of this work it is necessary to add to the force from time to time. At present this is done in two ways. It is our custom to have new Ph.D.'s go directly into the research divisions. The second source of new men is the analytical section which I have described. The choice of a man from the analytical division is made first, in order of seniority, and second, on individual qualifications for the position that is open. It is attempted to place the man where he apparently will be happiest and be in a position to develop best and become most valuable both from his own and the company's standpoint.

I might take this occasion to say that personally I believe it would be to the ultimate advantage of the Ph.D. if he too could be given training in the analytical division since the analytical approach to research problems has been demonstrated to be most fruitful. So far we have not been able to devote the necessary time to this training of Ph.D. chemists. In either case the new man starts to work with one of the older chemists. At first he is given a series of reactions or processes to carry out. He is closely watched and where faulty his technic is corrected. Within a reasonable period of time he is able to do the work satisfactorily and is then ready for research and development work on new processes. For some time this is carried out under the direction of the older man but finally when obviously qualified, the new chemist is ready to go it on his own, reporting directly to the Division Head. The length of this training varies according to the individual and is usually longer for the four- and five-year men than for the Ph.D.'s

During this period of training, it is of greatest importance that the chem-

ist realize his lack of knowledge and capitalize to the utmost the expert guidance which is at his disposal. He should approach his task with an aggressive desire to learn and should thoroughly study the literature pertaining to his field. He learns the controlling factors in obtaining high yields and good quality and is able to choose those methods which have the best economy both considered alone and in connection with other products being manufactured. His growth is in his ability to arrive quickly at the solution of a problem, while at the same time choosing that procedure which is fundamentally of greatest economy. He is a pioneer and his efforts frequently result in patentable processes which constitute the basis of a monopoly which in turn yields the richest profits. He should learn to analyze a problem and to plan his work systematically so that to a large extent his actual experiments are to confirm an idea or fact rather than that from a large number of experiments he should be able to deduce a fact. It is not by any means a training solely in the use of his hands or in the accumulation of a fund of highly specialized facts. It is a period of mind training which is a continuation of that training which the college should really aim to give its students.

It takes all kinds of men to make the world and this is fortunate. Some of the research chemists will always be individual workers while others exhibit the ability to handle many problems and ultimately are able to go into managerial positions. It should not be assumed, however, that financial success is predicated solely on being able to go into executive work. Some of the most inventive chemists are those who shun personal contacts and office work. They contribute in an important way to the success of the developmental work. We could not get along without the genius. It is desirable, however, to live harmoniously with others and the ability to coöperate is a vital part of the chemist's training. Too often an individual gets the idea that he can go it alone but finds in the end that he *is* alone and pretty much out of the picture. Individual effort persists until his extensive background and his outstanding organizing ability fit him to lead others and direct their work in a more coördinate whole. He then becomes a section leader, or an assistant division head—later a division head, then assistant laboratory director, and then laboratory or chemical director.

Another phase of the activities of the chemist in the Dyestuffs Department is in connection with the manufacturing end of the business. The plant is organized along lines very similar to those I have described in the research laboratory. It is composed of areas, again based on the natural divisions of the work. Roughly, these manufacturing areas correspond in subject matter to the divisions of the research laboratory. Each area has its own control laboratory in which the routine analysis of raw, semi-finished, and finished materials is carried out as well as a certain amount of

research work designed to improve the efficiency of the various operations. These laboratories handle the bulk of category (*a*) work and a fair proportion of (*b*).

Long ago it was decided that the manufacturing operations could be carried on most efficiently by highly trained chemists and the results in the last twelve years have amply substantiated this belief. We find, therefore, in the plant organization a large number of chemists. Some are in the plant laboratories and some are in actual charge of one or more operations. Most of the chemists in the plants came from the research laboratories, a few having been taken in from outside of the Company by virtue of experience gained with other companies. Many of the operating chemists were formerly in charge of divisions in the research laboratory and their collegiate training ranges from the four-year degree to the Ph.D. New chemists are obtained from either the analytical or research divisions of the research laboratory depending on the nature of the position to be filled. When they arrive they are familiar in a general way with the handling of large operations but must be trained in the particular processes being operated. Eternal vigilance to detail, the rigid control of purity, the prevention of mechanical loss, the efficiency of labor, the health and safety of the men, the economical treatment of repairs and replacements—all these must be mastered and much can be learned from the guidance and training given by the older men. Here, perhaps, more than in the research laboratory it is necessary to develop proper human relationships. The plant chemist has to deal with the research man who develops and hands over to him a process that is supposed to work. He must check it to be certain that he personally can operate it and obtain the desired results. He must maintain the proper contacts with the service departments so that his materials are on hand and his equipment in good operating condition. He must maintain the right spirit in his workmen. He must satisfy his superiors that maximum efficiency and minimum costs are realized. He must keep in touch with the technical and sales departments to make certain that he understands their requirements and delivers the desired amounts of products of high quality. Many times he contacts the customer in order to appreciate his needs or to solve the difficulties with the products he has sold.

The plant chemist grows in direct proportion to his ability to obtain high efficiency and this in turn is a direct reflection of his ability along the lines of chemistry, coöperation, originality, energy, and integrity. His route of progress is from assistant supervisor of one operation to complete charge of it—then to several operations, next an entire building, then an area of related products, then general production or chemical superintendent, assistant plant manager, and finally plant manager. It is a route of constantly increasing responsibility and effort and, of course, of increasing

recognition and financial return. His success depends on himself first of all but next on his training and to this extent his employer is responsible for his success. His progress is beset by trials and tribulations, it is sweetened by the thrill of achievement, lifelong friends are made, independence is acquired, and a satisfaction comes from the knowledge that one's best efforts have been expended and the goal reached to the best measure of one's ability.

ON THE USE OF EMPTY CHEMICAL BOTTLES

HARRIETT FILLINGER, HOLLINS COLLEGE, HOLLINS, VIRGINIA

Large empty glass bottles in which chemicals were purchased have been found very convenient and economical for use in certain lecture experiments in which the apparatus is quite likely to be broken.

As is generally known, experiments demonstrating the properties of oxygen, or other gases collected over water, almost surely result in the cracking of at least one cylinder. For instance, when burning iron wire in oxygen, one can hardly avoid cracking the apparatus, which is usually a cylinder of small diameter.

However, if a glass bottle of a liter and a half or two liters capacity is substituted for the demonstration cylinder in the above experiment the larger volume of oxygen makes success more certain, the experiment more convincing, and the breakage of the container of little consequence.

Oxygen Lack Produces Condition Like Insanity. An emotional and mental condition resembling the effects of alcohol or temporary insanity results from a lack of oxygen such as that experienced by the aviator flying at high altitudes. Marked effects on the personality and mental processes of oxygen deprivation were brought out by experiments reported to the New York branch of the American Psychological Association by Dr. Ross A. McFarland of Columbia University. The results of these experiments may lead to the development of new methods of studying the physiological and psychological causes of mental breakdown, Dr. McFarland believes.

Loss of memory results from the lack of oxygen at altitudes of 20,000 feet or more, and even below that height persons become unable after a period of an hour to keep their attention fixed or to perform tasks requiring judgment, patience, or persistence. These effects occur in an insidious manner. The subjects make mistakes but are not aware of them.

Emotional outbursts are characteristic but individuals differ widely in their reactions, Dr. McFarland said. "Some reacted by marked irascibility of temper or by trying to break the apparatus to pieces, others by uncontrollable laughter, silliness, or flirting with the experimenter. There seemed to be some consistency in these reactions suggesting that the basic and uninhibited temperament of the individual had been exposed. Lack of effort, indifference, and lack of ability to carry out tasks are very characteristic and quite as noticeable as the loss in accuracy."—*Science Service*

REPORT OF THE COMMITTEE ON PRIZE ESSAYS AT THE END OF THE CONTESTS (1923-1931) CONDUCTED UNDER THE AUSPICES OF THE AMERICAN CHEMICAL SOCIETY WITH FUNDS PROVIDED BY MR. AND MRS. FRANCIS P. GARVAN OF NEW YORK CITY

At the meeting of the American Chemical Society held at New Haven, Connecticut, in the Spring of 1923, the desire of Mr. and Mrs. Francis P. Garvan of New York City to provide funds for the Society to conduct a national essay contest for high and secondary school students was announced and enthusiastically received. This took form with an exchange of letters between Mr. Garvan and the Society as follows:

Council of the American Chemical Society, June 1, 1923
Mills Building,
Washington, D. C.

Gentlemen:

In order that the youth of our country may have an intelligent appreciation of the vital relation of the development of chemistry to our national defense, to the intensification and purification of industry and agriculture and to the progress of medicine through the "Age of Chemistry" upon which we have entered, and in memory of our daughter, Patricia, Mrs. Garvan and myself tender to you the sum of ten thousand dollars. Six thousand dollars is to be expended by you in awarding in each State six prizes of twenty dollars in gold to the students in all secondary schools, public and private, for the six best essays evidencing an understanding of the importance of chemistry in our national life. The remaining four thousand dollars is to defray the expenses of the contest.

In addition, we have provided for six four-year scholarships in chemistry, or chemical engineering at Yale University or Vassar College,* to be awarded by you among the successful students in each of the several States. These scholarships will carry five hundred dollars a year and tuition. The choice of subjects, all rules and regulations governing the contests, the awarding of the prizes, and scholarships, et cetera, are to be under your absolute control and direction.

Sincerely yours,
FRANCIS P. GARVAN

Mr. Francis P. Garvan, August 21, 1923
67 Wall Street,
New York, N. Y.

Dear Mr. Garvan:

On behalf of the American Chemical Society and upon the authorization of its Council it gives me great pleasure to accept the gift of Mrs. Garvan and yourself in memory of your daughter, Patricia.

Your plan by which a more extensive interest in chemistry will be engendered has the enthusiastic approval of the Society. I have, therefore, appointed a committee composed of H. E. Howe, Chairman, W. D.

* Upon further consideration it seemed desirable to permit each prize winner to select his alma mater, and this change in the conditions of the contest was made before any prizes had been awarded.

Bancroft, Chas. H. Herty, and Alexander Williams, Jr. (Secretary), to organize and carry forward this work.

Believe me, Sir,

Very sincerely yours,

E. C. FRANKLIN
President

High-School Contest

The administrative committee appointed by President Franklin immediately began the organization of the contest. After consultation with Mr. Garvan and with leaders in the educational field, a definite plan of procedure was adopted. The plan proposed by Mr. Garvan provided prizes for a separate contest in each state, and further, provided six scholarships of an average of $3600 each, to be distributed among the winners of the state contests. It was, therefore, necessary to conduct each state contest as a unit and enter the winners of such contests in a final or national competition for the six four-year scholarship prizes. In consonance with this plan a committee was organized in each state, whose function was to create interest in the contest locally, to examine the hundreds of essays submitted at the close of the contest and select the winners, to distribute the state prizes, and to enter the winners in the national contest. To take care of the selection of the best essays in the final competition a committee composed of nationally known individuals was formed and the majority vote of this committee determined which essays merited the national scholarship prizes.

The immediate and enthusiastic replies received by the committee from those invited to become members of the national and state committees, coupled with the eagerness of high-school principals and chemistry teachers to participate in the contest brought early assurance to the committee in charge that the contest would be successful.

President Hoover, then Secretary of Commerce, readily accepted the chairmanship of the National Committee, and on entering the White House relinquished the post to Dr. Ray Lyman Wilbur, Secretary of the Interior. Others who served on the National Committee were:

LAWRENCE F. ABBOTT, JANE ADDAMS, DR. JAMES R. ANGELL, DR. LEO H. BAEKELAND, LOUIS BETTS, MRS. ALFRED BROSSEAU, WALLACE BUTTRICK, JAMES BYRNE, HON. ARTHUR CAPPER, EMMA P. CARR, BRIG.-GENERAL JOHN J. CARTY, MRS. ANTHONY WAYNE COOK, ROBERT J. CUDDIHY, ALBERT B. DINWIDDIE, GEORGE EASTMAN, RICHARD H. EDMONDS, FREDERICK P. FISH, ERNEST FLAGG, LEE K. FRANKEL, GILBERT GROSVENOR, DR. WM. D. HAGGARD, DR. MALCOLM L. HARRIS, MRS. LOWELL FLETCHER HOBART, DR. EDWARD STARR JUDD, DR. H. N. MACCRACKEN, DR. CHARLES H. MAYO, DR. JOHN C. MERRIAM, DR. ROBERT ANDREWS MILLIKAN, DR. WM. GERRY MORGAN, DR. JAMES F. NORRIS, DR. WENDELL C. PHILLIPS, MARY ROBERTS RINEHART, JULIUS ROSEN-

WALD, MRS. JOHN D. SHERMAN, DR. EDGAR FAHS SMITH, IDA M. TARBELL, DR. WM. S. THAYER, HENRY B. THOMPSON, H. J. THORKELSON, MERLE THORPE, HON. JAMES W. WADSWORTH, JR., MAUDE A. K. WETMORE, FREDERICK EDWARD WEYERHAEUSER, W. R. WHITNEY, MRS. ALICE AMES WINTER, MATTHEW WOLL, DR. A. F. WOODS.

Of equal importance to the success of the contest were the men who acted as chairmen of the state committees. The responsibility for the fair and proper conduct of the state contests rested on the shoulders of these chairmen and their committees, who discharged their duties conscientiously and satisfactorily. These carefully selected committees were composed of prominent individuals whose sponsorship of the contest in their communities attracted many additional thousands who otherwise might not have enjoyed its benefits. The state committees campaigned vigorously to arouse the interest of the teachers and educational officials in their respective states, using the radio, personal contact, public addresses, and correspondence as their media of approach. These state committees not only contributed their time and effort but many expended substantial sums out of their own pockets to further their local contests. Space does not permit our listing the names of the 987 members of these state committees as we should like to do and we must content ourselves with listing those who directed the committee activities in their state as chairmen:

Alabama—VICTOR HANSON, DR. C. C. CARMICHAEL; *Arizona*—DR. CLOYD H. MARVIN, DR. ERNEST ANDERSON, DR. L. E. ROBERTS; *Arkansas*—G. W. ROARK, JR., DR. J. W. READ, DR. HARRISON HALE; *California*—WILL C. WOOD, WILLIAM J. COOPER, VIERLING KERSEY; *Colorado*—DR. W. D. ENGLE; *Connecticut*—PROFESSOR TREAT B. JOHNSON; *Delaware*—CHAS. M. STINE, CHAS. L. REESE, G. M. NORMAN, J. L. BENNETT; *District of Columbia*—WM. KNOWLES COOPER, DR. GEORGE L. COYLE; *Florida*—DR. TOWNES R. LEIGH; *Georgia*—DR. J. L. MCGHEE. HON. L. G. HARDMAN; *Idaho*—ELIZABETH RUSSUM, MRS. MAYBELLE M LYMAN, MISS MYRTLE R. DAVIS; *Illinois*—THOMAS E. WILSON; *Indiana*—DR. C. B. JORDAN, FRANK B. WADE; *Iowa*—DR. W. F. COOVER; *Kansas*—HON. HENRY J. ALLEN; *Kentucky*—DR. F. E. TUTTLE, DR. HOWELL D. SPEARS, DR. J. STANTON PIERCE; *Louisiana*—DR. H. W. MOSELEY; *Maine*—DR. C. A. BRAUTLECHT, F. W. ADAMS, DR. ARTHUR B. ANDREWS; *Maryland*—CARL HANER, H. A. B. DUNNING, DR. LOUISE KELLEY; *Massachusetts*—FRANKLIN W. HOBBS; *Michigan*—FRANK O. TAYLOR; *Minnesota*—DR. CHARLES A. MANN, DR. J. J. WILLAMAN, DR. A. D. HIRSCHFELDER, DR. H. H. BARBER; *Mississippi*—DR. JOHN N. SWAN, DR. G. H. WOOLLETT; *Missouri*—EDWARD MALLINCKRODT, JR., DR. GEORGE T. MOORE, W. R. TEETERS; *Montana*—DR. R. H. JESSE, DR. W. M. COBLEIGH, DR. R. E. KIRK; *Nebraska*—WM. M. BARR; *Nevada*—DR. MAXWELL ADAMS; *New Hampshire*—DR. HUGH K. MOORE; *New Jersey*—DEAN WILLIAM F. MAGIE, PROF. R. G. WRIGHT, E. W. SCUDDER, DR. DAVID WESSON, A. E. PARMELEE; *New Mexico*—DR. JOHN D. CLARK; *New York*—DR. NICHOLAS MURRAY BUTLER; *North Carolina*—

DR. A. S. WHEELER, PROFESSOR L. F. WILLIAMS; *North Dakota*—DR. G. A. ABBOTT; *Ohio*—M. E. DANFORD, PROF. A. W. SMITH, J. L. CLIFTON; *Oklahoma*—E. E. TOURTELLOTTE, CLIFF R. OTTO, C. K. FRANCIS, PROFESSOR H. M. TRIMBLE; *Oregon*—J. A. CHURCHILL, C. A. HOWARD; *Pennsylvania*—DR. H. S. DRINKER, MILTON CAMPBELL, DR. GERALD L. WENDT, DR. FRANK C. WHITMORE; *Rhode Island*—DR. W. H. P. FAUNCE, HOWARD D. DAY, DR. LUCIUS BIGELOW, DR. NORRIS W. RAKESTRAW; *South Carolina*—DR. R. N. BRACKETT; *South Dakota*—DR. R. A. DUNBAR; *Tennessee*—DR. H. A. MORGAN, PROFESSOR C. O. HILL; *Texas*—PROFESSOR HARRY B. WEISER; *Utah*—DR. GEORGE THOMAS; *Vermont*—DR. PAUL D. MOODY; *Virginia*—HON. CARTER GLASS, DR. EDWIN A. ALDERMAN; *Washington*—WORRELL WILSON; *West Virginia*—GEORGE M. FORD, WILLIAM C. COOK; *Wisconsin*—DR. J. H. MATHEWS; *Wyoming*—LEWIS C. TIDBALL, N. D. MORGAN, B. H. MCINTOSH.

The administrative committee cannot praise too highly the quality of the service which has been rendered by the members of the state and national committees in the advancement of chemical knowledge.

The next step in organizing the contest was to prepare a list of subjects for the essays which would be attractive, useful, and comprehensive.

The following six subjects were finally selected: (1) The Relation of Chemistry to Health and Disease, (2) The Relation of Chemistry to the Enrichment of Life, (3) The Relation of Chemistry to Agriculture or Forestry, (4) The Relation of Chemistry to National Defense, (5) The Relation of Chemistry to the Home, (6) The Relation of Chemistry to the Development of the Industries and Resources of Your State.

The administrative committee next prepared appropriate literature to explain and advertise the contest. The result was a booklet containing the rules of the contest, the six subjects under which the essays must be written, a suggested list of reference books and other relevant matter. There was also prepared a colorful display poster for the high-school bulletin boards. Ten copies of the booklet and a display poster were sent to 14,798 high schools in the United States. This literature was accompanied by an explanatory letter urging coöperation and explaining that all were eligible to participate. During the course of the school year several follow-up letters of a similar nature were distributed to these 14,798 schools. In addition to the distribution of this literature to the high schools, hundreds of public and private libraries were communicated with and were likewise sent booklets and posters. One of the welcomed sources of real assistance came from these librarians, who were only too willing to assist the high-school boys and girls to sources of reference for their essays.

A preliminary survey by the administrative committee emphasized the necessity for the distribution of some popularly written books on chemistry as sources of reference for the essays, for it was found that many of the high schools in the United States completely lacked material of this type.

The coöperation of The Chemical Foundation, Inc., was sought in this connection and the Foundation generously agreed to do its part in this educational movement and arranged with the administrative committee to donate a set of five books to every high-school library and to public and private libraries as well. The books donated by The Foundation were: "The Life of Pasteur," by R. Vallery-Radot, "Discovery—The Spirit and Service of Science," by R. A. Gregory, "Creative Chemistry," by Edwin E. Slosson, "The Riddle of the Rhine," by Lefebure, and "The Future Independence and Progress of American Medicine in The Age of Chemistry," by a Committee of American Scientists. In this way, 21,350 sets of these five books were distributed throughout the schools of the United States and in many instances were the beginnings of what have since grown to be helpful chemical libraries. The Chemical Foundation, Inc., likewise agreed to donate these books to the administrative committee for distribution to the members of the state and national committees and to prominent educators and educational officials. The good results of the wide distribution of these books cannot be over-estimated. There are countless instances of specific benefit, such as the case of a prominent college president, who, until he read "Creative Chemistry" and "The Life of Pasteur," had a distinct aversion to chemistry, which was in turn reflected in the paucity of funds allotted to the chemistry department of his college each year. The reading of these two books was the beginning of the conversion of this college president from a tolerator of chemistry to one of its best friends. His present attitude is reflected in the growth of the chemistry department of his college and likewise in his public addresses where he invariably takes the opportunity to point out to his audience how vitally each is affected by chemistry. The administrative committee knows of the conversion of many public officials charged with the allotment of the public funds for school use and of many cases where appropriations for the creation of high-school chemistry departments and the building of decent laboratories have resulted from the campaign of education which the essay contest launched.

It is appropriate here to mention that the American Chemical Society's Essay Contest has been accepted throughout the United States as a purely educational project. Many of the larger cities that had official regulations barring the ordinary type of commercial essay contest were quick to waive the application of such regulations in favor of the chemistry essay contest.

As the contest progressed, the administrative committee learned that the close coöperation of the chemistry and English departments was essential for a successful contest in each school. Therefore, a special effort was made to arouse the heads of the English departments and the majority readily responded to the invitation to coöperate, many of them

utilizing the suggestion that they treat the essays for the contest as one of the required themes of the first half year. In this way the contest essays were doubly useful and attractive to the students and at the same time brought an acquaintance with present-day chemistry to thousands of English teachers whose interest in the science had become dormant.

In the succeeding seven annual high-school essay contests the same procedure was followed except that a few modifications were made as experience accumulated.

During the eight years of the contest there has been distributed $48,960 in $20.00 gold pieces to the first-prize winners in the state contests and to the winners of honorable mention in such contests have been distributed 4200 books and each of these winners has also received an inscribed certificate signed by the committee in charge and by the state chairman. In addition to the distribution of these state prizes, the administrative committee has attended to the awarding of the forty-eight national prizes. These awards, approximating a total value of a quarter of a million dollars, have gone to 26 boys and 22 girls. Eighteen have graduated from college, eighteen are now in college, five will enter college this fall and three in the fall of 1932. The eighteen who have graduated from college are as follows:

ELTON R. ALLISON, Centralia, Wash., *University of Washington*, 1928 M.A.; DOROTHY L. BAKER, Braintree, Mass., *Radcliffe College*, 1931 A.B.; E. R. BROWNSCOMBE, Santa Rosa, Calif., *Yale*, 1928 B.S.; EUPHEMIA M. CLARK, Reno, Nevada, *University of Nevada*, 1931 A.B.; SHIRLEY C. CORDILL, New Orleans, La., *Vassar*, 1929 A.B.; GEORGE B. CRUMP, Pine Bluff, Ark., *Yale*, 1931 B.S.; ELIZABETH DAWSON, Indianapolis, Ind., *Butler University*, 1930 A.B.; DUDLEY L. HARLEY, Mercersburg, Pa., *Lehigh University*, 1930 A.B.; *Harvard*, 1931 M.A.; WALLACE D. HERRICK, Mitchell, S. D., *Carleton College*, 1931 A.B.; MARION HONKE, Carroll, Iowa, *Northwestern University*, 1929 B.S.; RUTH JAMIESON, Whittier, California, *Whittier College*, 1929 A.B.; V. A. MCKIVERGAN, Providence, R. I., *Brown University*, 1930 M.A.; ROGER S. MAKEPEACE, Andover, Mass., *Yale*, 1929 A.B.; BENJAMIN NASSAU, Hartford, Conn., *Yale*, 1928 B.A.; OLIVER C. PITTMAN, Commerce, Ga., *Yale*, 1931 B.S.; JAMES COLE REID, Dallas, Texas, *Yale*, 1929 A.B.; FRANK WHITELEY, Bisbee, Ariz., *Stanford University*, 1931 A.B.

The eighteen now attending college are:

JOHN STANLEY BANCKER, Tilton, New Hampshire, *Yale;* C. JELLEFF CARR, Hamilton, Md., *University of Maryland;* GUINEVERE CROUCH, Boise, Idaho, *University of Washington;* DORIS E. DIERKES, Philadelphia, Pa., *University of Pennsylvania;* EDWARD GREGG, Las Cruces, New Mexico, *New Mexico College of Agric. & Mech. Arts;* RUTH M. KNOBEL, Kalispell, Mont., *University of Wisconsin;* RUTH LESLIE, Bonham, Texas, *University of Texas;* ESTHER LAINE, Bisbee, Ariz., *University of Arizona;* JOHN E. LIVAK, Rutland, Vt., *Yale;* WILLIAM MCWHORTER

LOEHR, Waukegan, Ill., *University of Chicago;* JOHN DOUGLAS MARTIN, St. Louis, Mo., *University of Missouri;* PAUL MICELI, New London, Conn., *Harvard;* PATRICIA S. MORONEY, Manchester, Conn., *Cornell;* JOHN B. RAE, Providence, R. I., *Brown University;* RUTH SCRIBBINS, Winnetka, Ill., *DePauw University;* SYLVIA SIMON, Trenton, N. J., *Cornell;* A. P. SMITH, Chapel Hill, North Car., *University of North Carolina;* MORGAN L. WALTERS, Rock Springs, Wyo., *Stanford University.*

The five who will matriculate this fall are:

MARGARET COX, La Crosse, Wis., *St. Mary's College;* FRANCES GELABERT, Tulsa, Okla., *Smith College;* GERALDINE E. RHOADS, Belleville, N. J., *Bryn Mawr;* ALEX SCHEER, Kenosha, Wis., *Stanford University;* MARJORIE SHUMACKER, Chattanooga, Tenn., *Wellesley College.*

The three who will matriculate in 1932 are:

J. STEWART BARNEY, Brattleboro, Vt., ELIZABETH DEW, Arkadelphia, Ark., ANNE STRINGER, Baltimore, Md.

The States which have provided the national prize winners and the number from each follow: Alabama 1, Arizona 4, Arkansas 1, California 2, Connecticut 3, Georgia 1, Idaho 1, Illinois 2, Indiana 1, Iowa 1, Louisiana 1, Maryland 2, Massachusetts 2, Missouri 1, Montana 1, Nevada 1, New Hampshire 1, New Jersey 2, New Mexico 1, North Carolina 1, Oklahoma 1, Oregon 1, Rhode Island 2, Pennsylvania 2, South Dakota 2, Tennessee 1, Texas 3, Vermont 2, Washington 1, Wisconsin 2, Wyoming 2.

The high-school essay contest, in the opinion of the administrative committee, has been conspicuously successful. That our country generally is today alive to the importance of chemistry is apparent on every hand. This awakening is shown in the growth of the chemical industry here, the increase in chemical literature and the prominence given to chemistry by our daily newspapers. The administrative committee is of the opinion that much of this awakening in every quarter of the United States had its origin in the interest in chemistry aroused by the high-school essay contest.

Thousands of students have written Mr. and Mrs. Garvan and the committee expressing appreciation of the fact that the essay contest has brought them an understanding of chemistry in modern life. Not only have the four million participants acquired a better understanding of chemistry, but they have likewise brought the contest into their homes and aroused the interest of their parents and friends. Typical of this is a letter written to Mr. and Mrs. Garvan by Arthur Bassett of the Baraboo High School, Baraboo, Wisconsin:

"This contest has meant much more to me than simply the reward, because had it not been for the Essay Contest I would not have appreciated what chemistry means to the welfare of all of us. Besides myself, my

whole family and friends have taken a great interest in chemistry. I feel that this Essay Contest which you sponsored is of great value in getting people to realize what chemistry is and what it is good for."

College and University Contest

The returns of the 1923–24 contest so satisfied Mr. and Mrs. Garvan that the country had caught the spirit of the project that they offered an additional $6000 to be awarded as prizes for a similar contest to be open to all students in the colleges and universities of the United States. This contest was launched in the fall of 1924. At first the same essay topics and rules were used as in the high-school contest, but subsequently a change was made in both topics and rules adapted to the higher grade of participant. Appropriate literature was prepared and distributed to 923 colleges and universities, and at the same time correspondence with the heads of the respective chemistry departments was undertaken. Convinced after two years that it was not just to place freshmen and upper classmen on the same basis in a competition such as this, and investigation having shown that the freshman year at college was the best in which to use the essay contest the administrative committee changed the regulations of the contest in 1926, and restricted it thereafter to freshmen. The advantage of this change was immediately apparent and the close coöperation of the instructors in charge of freshmen chemistry and English was readily given. The contest has greatly stimulated interest in chemistry in the freshman classes in our colleges and universities.

Contest for Teachers' Colleges and Normal Schools

In his annual letter tendering funds for the following year's contest, addressed to the American Chemical Society on March 31, 1926, Mr. Garvan said:

"Recognizing the important place of the teacher, we wish to encourage a greater interest in chemistry among those preparing to give instruction in our various schools. We therefore desire to offer cash prizes totalling $6000 which will be awarded for the best essays on the group of six selected subjects written by students in the normal schools and teachers' colleges of the country in accordance with rules to be laid down by your committee."

The administrative committee prepared appropriate literature, using the same procedure as in its two other contests. The invitation to participate was given to 259 colleges and normal schools. The contest increased interest in chemistry in these institutions to a marked degree.

The prize essay contest in chemistry raised problems of administration and policy which had no precedent, but all difficulties were met successfully by the several committees.

The administrative committee has enjoyed the privilege of directing the essay contest for Mr. and Mrs. Francis P. Garvan and the American Chemical Society and relinquishes its task with the conviction that the wishes of the donors as expressed in their letter of June 1, 1923, to the Society have been fulfilled.

COMMITTEE ON PRIZE ESSAYS
NEIL E. GORDON, *Chairman*
LYMAN C. NEWELL
CHAS H. HERTY
PAUL SMITH, *Secretary*

Eddington's Physical Conception of the End of the World. A physical conception of the end of the world formed the basis of the presidential address delivered by Sir Arthur Eddington on January 5 before the Mathematical Association at the London Day Training College. The world, or space-time as Sir Arthur Eddington called it, was shown to be a four-dimensional continuum, thus offering a choice of many directions to take in order to look for the end. From a space-dimensional point of view the world is spherical; but then the time dimension must be considered too. This consideration formed the basis of the lecture. Entropy, that is, the measure of the disorganization of a system, was suggested by Sir Arthur as being the fundamental theme upon which to work. Despite the phenomenon of evolution, whereby all types of systems have become and are still growing more highly organized, there is, on the whole, a general loss of organization. Such ever-increasing organization will perforce swallow up finally the organization due to evolution. Sir Arthur Eddington emphasized this conception showing that finally the whole universe will reach a state of complete disorganization, a uniform mass in thermodynamic equilibrium. This would be the end of the world. He considered finally what such an end would be like; but, realizing that the doctrine of spherical space and the results connected with the expansion of the universe have become modified, he merely made one of several possible suggestions. Taking the widely supported hypothesis that matter slowly changes into radiation, he suggested that the world will finally become a ball of radiation, growing ever larger, with the radiation becoming thinner and assuming longer wave lengths. About every 1,500,000,000 years the radius would be doubled, and this increase would carry on in geometrical progression.— *Nature*

Fish Blood Rich in Phosphorus. Studies upon the compositions of the blood of different animals which have just been completed at Cornell University show that the blood of the lower forms such as fish and turtles contain nearly three times as much phosphorus as those of the higher mammals. Fish have long been reputed to be high in phosphorus but the various forms in the blood have not been studied previously. Most of the phosphorus of fish blood is concentrated in the red cells.

This high phosphorus value for fish blood is interesting in the light of the meat diets used for rearing trout in most hatcheries. Brook trout grow to maturity upon food that is very rich in phosphorus, such as beef liver. One might expect bloods rich in phosphorus among the carnivorous fish but not among the omnivorous, such as carp. The bloods of both pike and carp were analyzed, however, and found to be equally high.— *Science Service*

A COMPARISON OF SCIENCE CURRICULA IN EUROPEAN AND AMERICAN SCHOOLS*

P. R. Neureiter, Western Illinois State Teachers' College, Macomb, Illinois

The education of a French and a German scientist is briefly outlined from the first grade up to the reception of the doctor's degree. The skeletons of the French and German school systems are drawn up, several representative curricula of the secondary schools in these two countries are analyzed, and the shares of science and the allied subjects determined. A chemist's training in a German university is briefly described.

The divergence between the American and the Continental systems of education is due principally to the absence of a European counterpart of the American high school. The secondary schools of France and Germany train only a small minority of the total school population selected on the basis of superior intelligence. Consequently instruction is exceedingly thorough University life throws the student upon his own initiative, and scores his progress by comprehensive and cumulative examinations. The concluding lines, expressing the author's opinion regarding the comparative merits of the American and European schools, urge the American high school to do more for the exceptionally gifted students who will be the future scientists of the country.

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The following attempt to parallel science education in America and Europe is made by one who has lived in Europe for twenty-eight years, who is entirely a product of European education, and has been an instructor in an American college for the last three years.

In order to familiarize ourselves with the rough outlines of the European school, system we shall pursue a French and a German boy on their educational careers from the first grade up to the happy point when they will be able to present themselves for the doctor's degree in one of the sciences. The picture thus obtained will hold good for a large number of countries as there is a striking resemblance between the educational systems in force on the continent. The schools of Great Britain, however, having their own distinctive traits, have been left out of this discussion.

A French child enters the grades at six, continues in them until the age of eleven when he, or rather his parents and teachers, have to make an important decision. Shall he go on to the higher elementary school, from which he will graduate at thirteen in order to take up a wage-earning job or to continue in a vocational school, or shall he become a member of the select minority who are given a thorough training in the "lycées" or "collèges," the secondary schools of the country?

* Paper read at the meeting of the Illinois State Academy of Science in Peoria, Illinois, May 8, 1931.

The child whose career we are pursuing will do well to transfer to the secondary school at this point. For this is the school from which he should graduate in order to enter the university and obtain the doctor's degree. Should he fail to enrol in the secondary school at this time he would not necessarily be barred from the access to higher education, but he would find it increasingly difficult to make the transfer at a higher age. It is a significant fact, however, that only about one-tenth of the pupils enrolled in the lower elementary schools go through the secondary schools while about nine-tenths limit their education to the opportunities offered by the other branch of the system. (See Figure 1.)

FRENCH SCHOOLS

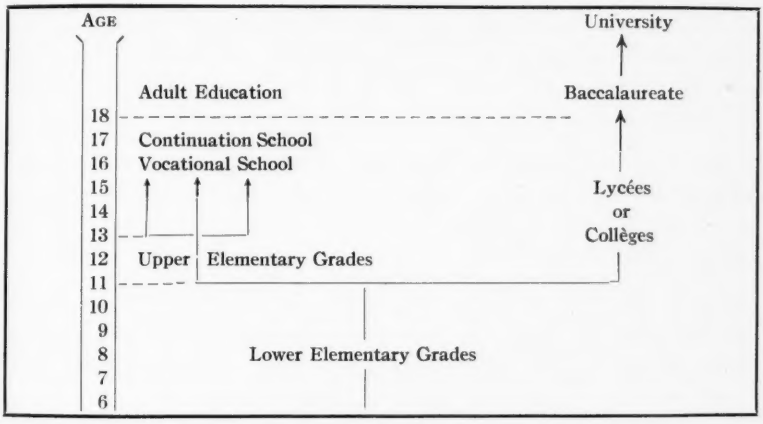

FIGURE 1. DIAGRAM ILLUSTRATING THE FRENCH SCHOOL SYSTEM

The French secondary school extends over seven years between the ages of eleven and eighteen, and offers a choice of two curricula in the lower four-year cycle, and of three curricula in the upper two-year cycle. The seventh year offers an option between the "Classe de Philosophie" and "Classe de Mathématique," laying emphasis on the literary studies, or mathematics and the sciences, respectively. Once a certain curriculum is chosen by the student, a definite set of subjects is prescribed, as the number of electives is negligible. It has been said that the European student has to get his education "Table d'hôte" while the American youngster has the privilege of studying "à la carte." If the number of weekly recitations continued throughout the year is totaled in each subject for the entire seven years, the time allotment for every subject, calculated on the basis of an average curriculum, is as follows (*1*):

Subjects	*Number of Recitations*	*Per Cent of Total Curriculum*
French	29	19.3
Foreign Languages	51	34
History	$16^1/_2$	11
Geography	5	3.3
Mathematics	$25^1/_2$	17
Sciences	20	13.3
Philosophy	3	2
Total Hours per Week	150	100

Since the efficiency of a school cannot be measured by the mere number of weekly recitations, it is the teaching process, too, that deserves consideration. The French have been traditionally proud of their secondary schools, and have strived to maintain the quality of instruction on a very high level. The instructors are selected by a competitive examination after having completed several years' work in the university. The curricula are frequently revised and overhauled by action of the government on recommendation of the Ministry of Public Instruction. Three principles are carried out in the organization of this school: first, that the incentive should not lie in the accumulation of points and credits, but in the ever-increasing mastery of a small number of subjects; second, that the school is to develop the minds of the students, rather than to fill them; third, that secondary education is intended for the intellectual pick of the nation, the élite, selected upon the merit of a superior intelligence. In conformity with these objectives a requisite for graduation from this school is the passing of a series of comprehensive examinations, both oral and written. These examinations, which include mathematics and the sciences, constitute the French

GERMAN SECONDARY SCHOOLS

	A	*B*	*C*	*D*	*E*	*F*	*Total % Min.*	*Max.*
Religion	18	18	18	18	18	18	7.1	7.1
German	37	35	31	35	37	44	12.2	17.3
Latin	40	53	41	16				20.9
Greek	32	36						14.2
1st Mod. Lang.	32	15	20	44	40	46	5.9	18.1
2nd Mod. Lang.			27	23	22	13		10.6
History	17	19	20	22	22	25	6.7	9.8
Geography	12	12	13	13	14	18	4.7	7.1
Mathematics	33	33	36	37	43	37	13	16.9
Sciences	18	18	25	23	35	30	7.1	13.8
Drawing	10	10	18	18	18	18	3.9	7.1
Music	4	4	4	4	4	4	1.5	1.5
Total	253	253	253	253	253	253		

A Reform-Gymnasium
B Gymnasium
C Real-Gymnasium
D Reform-Real-Gymnasium
E Ober-Real-Schule
F Deutsche Oberschule

FIGURE 2. COURSES OF STUDY OF GERMAN SECONDARY SCHOOLS

baccalaureate, are administered by university professors, and entitle to entrance into the university. They mark the end of secondary education as well as the beginning of specialization in a major field of the higher studies.

The German school system presents a very similar picture. All pupils stay in the grades between the ages of six and ten, when they arrive at the crossing of the roads. In Prussia about 88 per cent continue in the upper grades, later to enter trade, vocational, and compulsory continuation schools; about 12 per cent are regarded by their parents and teachers as the intellectual "gentry" and venture into the secondary schools where they are put through a most rigid training characterized by uncompromising Teutonic thoroughness. To cater to the diversity of interests this field of secondary education is covered by not less than ten different types of schools, each one having a definitely prescribed curriculum. The majority of these schools extend over nine years between the ages of 10 and 19, and give prolonged concentrated training in a limited number of subjects. The place of science in the curricula of these schools is illustrated by the tabulation in Figure 2 (*2*). Out of a total of 253 hours, representing the sum of all the weekly recitations continued throughout the year for the entire course of nine years, mathematics receives between 33 and 43 hours, or from 13 to 16.9 per cent of the total curriculum. Sciences comprising biology, physics, and chemistry receive 18–35 hours or from 7.1 to 13.8 per cent, the actual number depending on the type of secondary school.

The German boy or girl may graduate from this school at an age of 19 on passing the "Examination of Maturity" which, as in France, entitles him to enter the university, and being controlled by the universities, carries with it the admission to the institutions of higher learning.

Let me outline briefly the study of chemistry at a German university. At the very beginning of his work, the student selects his major and combines it with two minors which must be closely related to his major. A chemist will take courses in mathematics, physics, and mineralogy, but no other subjects outside of chemistry. (Some universities require a few courses in philosophy for the Ph.D.) His liberal education is officially closed at the age of 19 with graduation from a secondary school. University education finds its sole purpose in professional training. While the young man was under a strict discipline in the secondary school, he enjoys and frequently suffers from an almost unlimited amount of freedom in the university. There are no credits, honor points, quiz sections, or tests, but lectures at which attendance is voluntary, laboratory work of a definite content without a definite time schedule, and a few comprehensive and cumulative examinations. The rate of progress depends on the individual ability of the student. On an average, I estimate that the student will have finished his preparation in organic and inorganic, analytical and physical chemistry at

the beginning of the fourth year, and then will concentrate on the field in which he intends to work out his thesis. It will take him about three semesters to complete the dissertation so that during the tenth semester, or the latter part of the 5th year, frequently at an age of 24, he may obtain the Ph.D., provided that his thesis was approved and he passed a final examination in the major and minor subjects.

What does the comparison between the American and European school systems demonstrate?

Owing to the fierce competition of European life and the exigency of stringent economy, the aspirant to the highest degree in science is compelled to specialize early; he commences his scientific preparation at an age when the American youth has no reason to think or worry about his future. Consequently, the European can, if he pairs industry and ability, reach the highest professional degree at an earlier age than does the average American. At nineteen the German boy has at least a reading knowledge of two foreign languages, he has been through a continuous, methodical course of training in mathematics, including algebra, plane and solid geometry, trigonometry, analytics, and the elements of calculus; he knows the fundamentals of physics and chemistry. This intensive training is only attainable through the segregation of the pupils on the secondary level. There is no counterpart of the American high school on the continent. Over against one high school which in America educates the vast majority of the population, and consequently is burdened by a multiplicity of aims and objectives, Europe sets a differentiated system of secondary education with a variety of diverse schools, each one of which aims at a well-defined purpose, serves a specific end. The great majority of the people do not expect to obtain any professional training in the university; therefore, they stay away from those secondary schools which prepare their pupils for university entrance by a difficult condensed course of training.

The European continent has nothing to place side by side with the American college. The unique experience of college life with its subtle values, so eminently educative for the future citizen, is not duplicated in the continental university. There the student is prematurely forced into the narrow path of specialization; except in his seminar work he lacks guidance, lacks encouragement, and those beneficial influences which tend to mold him into a good citizen.

Should I be permitted to express my very personal opinion on the comparative merits of the two systems, I should say that they must necessarily be different since they have to be adapted to different economic and sociological conditions; that the American Liberal Arts College is superior to anything that European education has to offer; lastly, that the American public high school could do a still greater service to the nation if it gave more attention to the needs of the exceptionally gifted students, the intel-

lectual cream of the nation from whose ranks will be recruited the scientific workers of America.

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Faults Located in Rails Which Deceive the Eye. Telling what the inside of a sound-looking locomotive rail is like, without waiting for a train wreck to disclose the fact, is an achievement of science that is daily saving lives. In a report to the American Institute of Electrical Engineers, H. C. Drake, engineer of Sperry Products of New York, explains how this is accomplished with the detector car, the new safety patrolman of the railroad.

The detector car, which is a small, self-propelled railway car, moves along the track at six miles per hour when examining rails. It labels the faulty rails whose smooth exterior deceives track walkers as to the hidden danger lurking in them. Operating on the principle that an electric current flowing through a rail must pass around any break in the metal, the detector car records this electrical deviation and marks the bad spot with a streak of paint.

Early in 1927, it was demonstrated in the laboratory that electricity could be used successfully to diagnose the ills, if any, of steel rails. After months of experimentation the first detector car was constructed for the American Railway Engineering Association.

Since its acceptance in 1928 by this group, detector cars have been placed in use on several railroads, and the number of bad rails located is mute evidence of the disasters averted. The human eye is always able to find cracks in rails extending to the surface, but it has remained for the detector car to see through the steel and prevent track failures, previously accounted for as "acts of God."—*Science Service*

Destructive Orchard Disease Found Hiding in Beehives. Bees have been proved foes as well as friends of orchards, by researches recently brought to a climax by Dr. H. R. Rosen of the University of Arkansas. He has found the bacteria that cause fire blight, an exceedingly destructive disease in apple and pear orchards, are carried home by bees and that the infection is thus kept warm and alive over winter in the hives, ready for re-distribution in spring.

The theory that the disease is spread by the organism over-wintering in the tree itself is discarded by Dr. Rosen. He sought for the bacteria in the sap that oozes out of the injured places on the branches, and found only one canker containing them. In general, these oozing spots were not found to appear in spring until the bees were in flight. Although the bacterium can over-winter in injured tissue, Dr. Rosen found no evidence that they caused outbreaks of fire blight in the spring.

The theory that fire-blight outbreaks are due to bacteria over-wintering in the wood has been responsible for the methods used for combating the disease. At present injured places on the branches are cut out or pruned away before the development of new spring growth.

Dr. Rosen's work has shown this method to be quite useless. The way to stop fire blight is to make sure there is no infection in the beehives which must be maintained to insure the proper pollenation of the flowers. He is at present working on methods for detecting the presence of the bacteria in the hives and for removing the infection when found.—*Science Service*

A SUCCESSFUL OPEN-HOUSE PROGRAM

M. Merl Kindy, Franklin High School, Los Angeles, California

An open-house evening gives the chemistry teacher a splendid opportunity to sell his subject to the community. Most other departments are limited to "dead" exhibits. A "live" chemistry program combining pure entertainment with interesting practical demonstrations will be found to steal the crowds from the other departments and create enthusiasm for the subject. Such a program, put on in the chemistry laboratory at Franklin High School, was visited by approximately one thousand people.

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An "open-house" evening gives the adults a chance to visit the school, meet the teachers, and does much toward creating a friendly feeling between the school and the public. Chemistry teachers, in particular, have a splendid opportunity to create interest and enthusiasm in their subject. The question of what to show the people is naturally an important one. Unless the exhibit is alive and full of action, the people are apt to feel bored instead of enthusiastic.

Our school has had open house as an established annual custom for a number of years. It has been necessary for the chemistry department to evolve some successful plan for giving the people what they like best. We have tried practically every idea that has come to our attention. One year, regular classes were held with parents visiting. Another year, we had students performing typical laboratory experiments. The people were only mildly interested. We have featured posters, special projects, and other ideas.

For several years we have required each student who takes part in the open-house program to write up exactly what he did, and include the people's reactions, such as questions asked, comments overheard, and interest displayed. He is also asked to submit suggestions as to how his part might be improved. The teachers also have made note of where the crowds seemed to gather, and in talking with parents have watched for comments which indicated the part of the program they were most interested in. We thus have on paper a large number of ideas which have been used in the past, and this year we were in a position to select the best.

No claim is made that the experiments described are original. In fact, many are so old we don't know the source of the idea. Many of the old experiments, however, have been slightly modified to make them more effective for adult entertainment. The only thing we claim is to have studied rather carefully the psychology of the public, and to have given them this year a demonstration with enough action that none became bored.

Each student selected the experiment he wished to try, and most of them were given rather complete directions from previous years. Consequently, the whole program was worked up with a minimum of labor and confusion.

Approximately one thousand people saw the complete list of demonstrations. The program lasted from 7.00 P.M. until 8.45 P.M. In order to handle this large crowd we had arranged an orderly line of march which led past each demonstration.

As the people first came into the room they were greeted by a sight which caused them to rub their eyes and look again. The sign read, "The Original Fire Water," and there sure enough was genuine water running from the faucet, burning merrily. An ordinary aspirator was screwed into the faucet, but the rubber tube leading to a distant gas jet was so cleverly concealed that few saw it.

Moving on, the people next came to an exhibit of glass etching done by one of the chemistry students. For amateur work, her pictures were unusually good and produced much favorable comment.

Any student who had studied ionization could answer the next sign, "What Makes the Lamp Light?" but most of the grown-ups were still wondering when the evening was over. When they saw that shaking a little salt from an ordinary shaker into the distilled water made the lamp light, they were suspicious that there was a concealed switch somewhere. The only way to convince them that there was no trickery was to let them try it themselves.

The people have always been interested in the display of home-grown crystals. Viewed through reading glasses, the copper sulfate, sulfur, salt, alum, and Rochelle salt crystals were attractive enough to cause every one to stop and marvel. Some of the best displays of crystals were those which were purely accidental. One of the teachers prepared a salt solution for a sore-throat gargle and forgot to empty the beaker. A few weeks later some beautiful cubes were found in the dry beaker. A student forgot about a solution of copper sulfate and alum until she found the two almost completely separated into perfect crystals some days later. An artist could scarcely have planned a prettier pattern. Among the best of the crystal displays was the basket of "jewels," made by suspending a thread basket in an alum solution.

Coming to a student who was changing water to cherry punch and back to water again, most people of course suspected that the wet beakers contained some chemicals which were causing the color changes. The next demonstration however had them stumped. Here a red potassium permanganate solution was poured into a clean, dry, "empty" bottle, and became colorless instantly. No one could see the sulfur dioxide gas which partially filled the bottle. The student in charge of the generator was some distance away, and was bleaching colored flowers in addition to filling bottles for the potassium permanganate demonstration.

Next was a surprise lesson in dyeing, for the people saw red litmus paper, dipped into a red solution, come out blue, and blue litmus paper, dipped

into a blue solution, come out red. The blue solution was copper sulfate.

The "chemical" cake, and "synthetic" punch, have become an open-house tradition at our school. Girls are eager to volunteer to make the cakes, and we always have a large number of large cakes on hand when the people begin to arrive. Although each visitor is given only a mouthful for a sample, we never have had enough for all to get a taste. The cakes are made using any simple cake recipe, but substituting a calculated quantity of concentrated hydrochloric acid and soda for the baking powder. The public never ceases to marvel that cakes made with concentrated acid are good to eat.

Near where the cake and punch were being served were two girls using an apparatus to measure the amounts of carbon dioxide liberated by various brands of baking powder. The apparatus was similar to the one described in many laboratory manuals for determining the percentage of oxygen in potassium chlorate, except that a flask and dropping funnel replaced the test tube. A series of signs set forth the facts about baking powders, and the girls were glad to offer further explanation to any who were interested.

A little farther on were two girls with a reflux distilling apparatus, preparing fragrant esters. Samples of previously prepared ethyl acetate, amyl acetate (banana oil), and methyl salicylate (wintergreen) were given the people to smell. Most folks were interested in the odors if not in the apparatus.

Next to catch the attention was a magic pitcher which was being used to pour out water of almost any color desired. The students were specializing in red, white, and blue. The beakers were first filled with water from the pitcher, then two at a time were emptied back into the pitcher. When again poured out the water was colored. It is not difficult to find pairs of ions to produce almost any color.

As the people passed a vessel containing carbon dioxide snow, they were invited to take some. The extreme coldness startled all of them.

A very dramatic experiment, if properly done, is the solidifying of alcohol and a calcium acetate solution. The two liquids suddenly harden about twenty seconds after being poured together. The student found by practice that he could pour the mixture back and forth between beakers about twice, having his motions timed so that the third time he inverted the beaker, the mixture had solidified and did not come out. The watchers' mouths literally drop open as they wonder what has happened to the liquid. It is more effective in this, as well as other demonstrations for entertainment, to call all colorless solutions water. The people are further surprised when they see this water burn.

Passing again from the ridiculous to the sublime, the people came to an exhibit of simple student projects, with samples of the original and final products in each case. One student had removed the scale from a tea-

kettle, had purified it and exhibited the pure white calcium carbonate, which he was explaining was useful in tooth pastes. Another had changed some brown cadmium oxide (which had been in the storeroom for years and never used) to useful white cadmium chloride. Still another was showing a sample of pure salt, which had been recovered from the crust along the shore of the Salton Sea, in Imperial Valley. The purified salt presented quite a contrast to the dirty crust, and was pure enough, that even though made months before, it had not caked in the slightest degree.

Although the next experiment was of no practical value, the women, in particular, were quite impressed. Some "chemical jello" which hardened in a few seconds, was being made from water glass and hydrochloric acid. Turned out of ordinary jello molds and colored with various indicators, the samples looked so attractive that the people had to be told not to eat them.

A teacher's office was used as a passageway between two laboratories. This had been converted into a beauty spot. Using a water-glass solution and crystals of colored salts, a student was growing beautiful chemical "flowers." Silver and lead "trees" were growing in tall graduates between these beds of flowers. Expressions of admiration were frequently heard. The only trouble with this exhibit was that people wanted to linger too long in this chemical garden.

Entering the next laboratory room the visitors were again made to doubt their eyesight. Here was a water faucet clamped to a ringstand with a full stream of water pouring from it, coming apparently from nowhere. Of course, the sign said it was being condensed by radio from the air, and there was a miniature aerial connected to the ringstand, but that seemed hardly possible, even in California. A fortunate circumstance had occurred, which gave the student in charge a chance to enlarge on this idea. A record dry spell had been broken by a heavy rain the day of open house (when this apparatus was set up) and it was still raining that evening. Some people stood as long as five minutes trying to solve the mystery of this water, without seeing the glass tube coming up from below and entering the faucet. The water coming down on the outside of the glass effectively concealed it.

A simple experiment that is always sure to attract attention is the one which we called "Educated Moth Balls." Tall cylinders of water are seen, with moth balls ceaselessly rising and sinking. The balls are floated, either by bubbles of hydrogen, or carbon dioxide, made in very small quantities by the action of sulfuric acid on either zinc, or sodium carbonate. When they reach the top, the balls turn over, lose the bubbles of gas and slowly settle.

The next exhibit was one of silvering mirrors. Using one of the standard formulas, some students were silvering test tubes, watch glasses, beakers, and flasks and succeeded in getting some splendid results.

One of the prize demonstrations came next. Using the well-known iodic

acid time reaction, two students were promising to make their solutions flash blue at precisely the end of any number of seconds asked for. This experiment was performed about thirty times that evening, with times ranging from seven to forty seconds, without missing the time more than one second all evening. A previously prepared graph told them the exact amount of water to add to delay the reaction any length of time. An amusing illustration of how it is almost impossible to predict what stunts will go over best was illustrated in this experiment. The students had secured a seconds pendulum from the physics department, and had arranged an electrical connection so that seconds were ticked by a telegraph sounder. This was installed only as a simple timing device, but the public found it about as interesting as any of the demonstrations. More than one insisted that the two dry cells were causing the pendulum to swing.

A sign, "Why Die? Get the Mechanical Heart!" was used to attract attention to a mercury heart, which kept up its mysterious beating all evening.

The well-known fire-writing stunt, where a spark of fire traces out any writing or picture previously made with a potassium nitrate solution, has always proved popular. This year two girls had prepared a number of clever cartoons. The used sheets were mounted over the blackboard, so that when the evening was over, all the cartoons were on display. One showing an old man trying to hit a golf ball was worthy of a prize.

An interesting experiment, whose glory was only slightly dimmed by some of the other demonstrations, was the ammonia fountain. By the time the people had reached this experiment, they were so used to the unusual, that they were partly prepared to see the water race uphill and change from red to blue.

The race between the blue and gold was very pretty, and attracted attention even though it came near the end of the exhibition. Advantage was taken of two time reactions, the iodic acid reaction which flashes blue, and the arsenious acid reaction which turns to a beautiful gold. The two solutions were prepared so that each reaction occurred in about twenty seconds. After the respective solutions were mixed in beakers, they were poured into large test tubes, on foot, and set up where all could see the finish of the race.

The last demonstration was the painting of pictures, in four colors, by spraying a solution of ferric chloride on an apparently blank paper. The papers had been previously prepared by painting with solutions of potassium thiocyanate, potassium ferrocyanide, and tannic acid, and drying. When mounted on an easel, and the ferric chloride solution sprayed on from an atomizer, a picture formed which was red, blue, gray, and white. Students were selected for this demonstration who had some artistic ability, and it was really surprising to see some of the splendid pictures they were

able to produce. This demonstration proved to be a fitting finale for the visitors.

The open house described above proved to be a huge success. It seemed to combine a happy mixture of the foolish and serious. Every one had a good time, students, teachers, and visitors. There were no dull spots in the list of exhibits.

We have learned at this school that the public does not attend open house to be educated. We instruct the students in charge of the demonstrations to be sure they understand the chemistry of their experiments, to avoid possible embarrassment, but to make no attempt to bore the public with an explanation, unless it is asked for. A little semi-foolish "chatter" pleases the people better.

It might be argued that the demonstrations described give the public the wrong impression of what we teach the students in school. We have not found it so. The parents understood that this did not represent typical class work, and none of them demanded that we show them that. The writer visited another open-house demonstration recently, where the experiments were all typical laboratory experiments. Students were preparing hydrogen, oxygen, testing for chloride and nitrate ions, etc. None of the people knew what a chloride or nitrate ion was, and their expression indicated that the students might just as well be trying to burn water.

Getting ready for the open-house demonstrations upset the regular chemistry classes for about two days. These two days were valuable, however, because teacher and pupils were "playing" together, and getting better acquainted than in a whole semester of class work. The pupils found the whole program a lot of fun and many entered into the regular class work with a new zest.

New Device Lessens Fire Hazard in Auto Accidents. A device that takes the fire risk out of turning over in an automobile by cutting off the ignition when the car tips at a dangerous angle has been invented by V. E. Yaw of Indianapolis. Thus the possibility of sparks showering from a broken live wire into spilled gasoline is eliminated.

The safety circuit breaker is essentially a rocker arm to which is attached a two-inch lead ball free to swing like a clock pendulum. The upper end of the arm contains sliding contact brushes that rest on stationary battery and generator terminals.

The device is expected to find wide application. Mr. Yaw pointed out that during the six months when he was perfecting his invention 21 motorists were burned to death in automobile accidents within a radius of 50 miles of Indianapolis, according to newspaper clippings.—*Science Service*

College Gets Benefit of Insulator Patent. Patents on a plastic material similar to bakelite, but made from corncobs treated with cresylic acid, have been granted to Prof. O. R. Sweeney, and have been assigned by him to Iowa State College, Ames. The material is highly resistant to chemical and electrical action and is intended primarily for insulation.—*Science Service*

A MODIFIED PERIODIC CLASSIFICATION OF ELEMENTS ADAPTED TO THE TEACHING OF ELEMENTARY CHEMISTRY*

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A modification of the Deming style periodic classification of elements is presented which is claimed by the author to be simple and easily adapted to the teaching of elementary chemistry. The "A" groups are all located together, as are all the "B" groups. The inert gases are assigned a new relative position, between the halogens of VII A and the alkali metals of I A and the name of the group has been changed to "transition" A to match Deming's nomenclature of group VIII in his table. Pictorial methods are introduced by using narrow spacing for the "B" group elements and colored backgrounds for the different types of elements.

. . . . . .

There comes a time in every course of general chemistry when the periodic classification of elements is studied. The position in the course is not necessarily determined by the place allotted in the textbook used, nor is the significance and emphasis laid upon this subject by the instructor determined by the amount of material given in the text. It is possible that every teacher of inorganic chemistry teaches this subject and determines its importance in his course according to his own evaluation of it rather than by the treatment accorded by the text. It is the purpose of this paper to present the experiences of the author in teaching this subject and to present a model of periodic classification, evolved from these experiences, that so far has proved to be simple and perfectly usable even by the beginning student.

Let us assume that the class has followed an outline of study covering the following subjects: the fundamental laws, theories and definitions that usually introduce the elementary course; oxygen, hydrogen, atomic theory, and the gas laws; water, solutions, equations, and chemical calculations, chlorine and hydrochloric acid, acids and bases in general, and then the fundamental differences between the non-metallic type of element and the metallic type of element. With this preparation, the ground is ready for the introduction of the periodic classification of elements and the study of the structure of the atom.

From the author's past experiences, it is now deemed more logical that the study of the structure of the atom should accompany the study of the periodic classification of elements rather than precede or follow it. By developing the fundamental ideas of the structures of the first ten elements, pointing out the relation of electron arrangement to the group in which the element belongs and at the same time placing emphasis on the relation of the "valence shell" structure of the atom to its chemical

* Presented before the Division of Chemical Education of the A. C. S. at Indianapolis, Indiana, April 1, 1931.

properties, the periodic table becomes a living representation of the structure of the element. The treatment just outlined should, of course, be restricted to the "A" group elements.

Then, by pointing out the significance of oxidation–reduction reactions, in terms of electron rearrangement or transfer, a study can be made of the "B" group elements and evidence introduced showing why the "B" group elements are more closely related to each other "horizontally" in the periodic classification than are the "A" group elements.

Thus, the periodic classification of elements can be made to become a thing of vital importance in the study of chemistry and can serve as a useful tool in successful teaching. It is not a difficult thing to go on from this point into the mechanics of chemical combination and to formulate the conception of polar and non-polar valence. The theory of ionization then follows in natural sequence.

It is suggested that now the study of the groups of elements may be undertaken by using a contrast method, *viz.*, alternate a non-metallic group with a metallic group—the halogen family, VII A, followed by the alkali metals, I A, then the sulfur group, VI A, followed by the alkaline earths, II A. Frequent reference can thus be made both to the periodic classification and the atomic structure, and the student's mind may be kept cognizant of the existence of two contrasting types of elements, the metallic and the non-metallic. This method can be made very effective.

It is the belief of the author that nothing has been indicated in the foregoing outline that is decidedly individual or extremely revolutionary. Now a question arises concerning the type of periodic classification that is best adapted to teaching the elementary student. There are a variety available: the Hubbard (*1*) and the simple Mendeléeff types, Deming's modification of the Werner style (*2*), the model described by Rodebush (*3*), and the various helix models, notably that of Monroe and Turner (*4*) which was recently published. The helix or spiral type is not usually considered adaptable to the use of the beginning student.

Now, if we should take a simple Deming type chart (Figure 1) and with a pair of shears cut the chart along the line between groups III A and IV B and then fit the two pieces together again so that the group VII A is one column to the left of the inert gases, some interesting things are apparent (Figure 2).

I. Now the "A" group elements are all together, as are all the "B" group elements.

II. The numbered groups occupy the same relative positions, regardless of whether they are of the "A" or "B" groups.

III. Again, the inert gas group has always been called the "Zero" group, while group VIII has been more or less difficult to explain satisfactorily to the beginning and inquisitive student. In Deming's table,

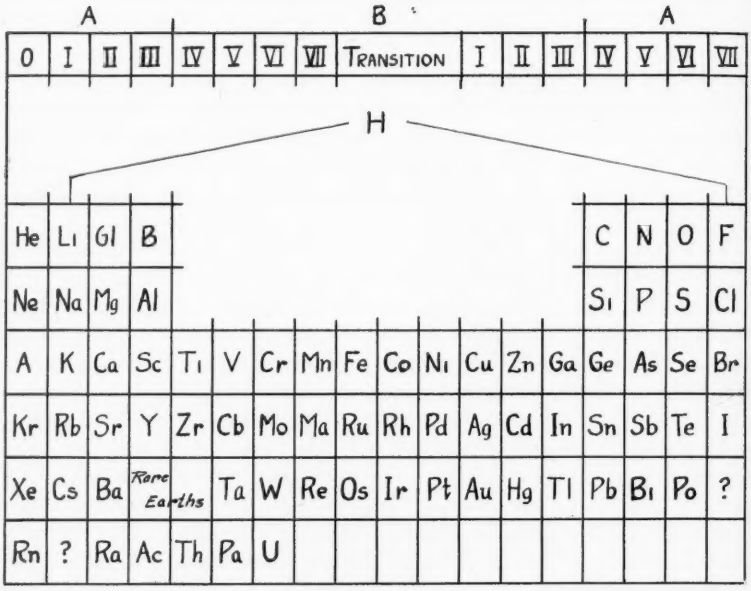
A
B
A
0 I II III IV V VI VII TRANSITION I II III IV V VI VII
H
He Li Gl B C N O F
Ne Na Mg Al Si P S Cl
A K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br
Kr Rb Sr Y Zr Cb Mo Ma Ru Rh Pd Ag Cd In Sn Sb Te I
Xe Cs Ba Rare Earths Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po ?
Rn ? Ra Ac Th Pa U

FIGURE 1

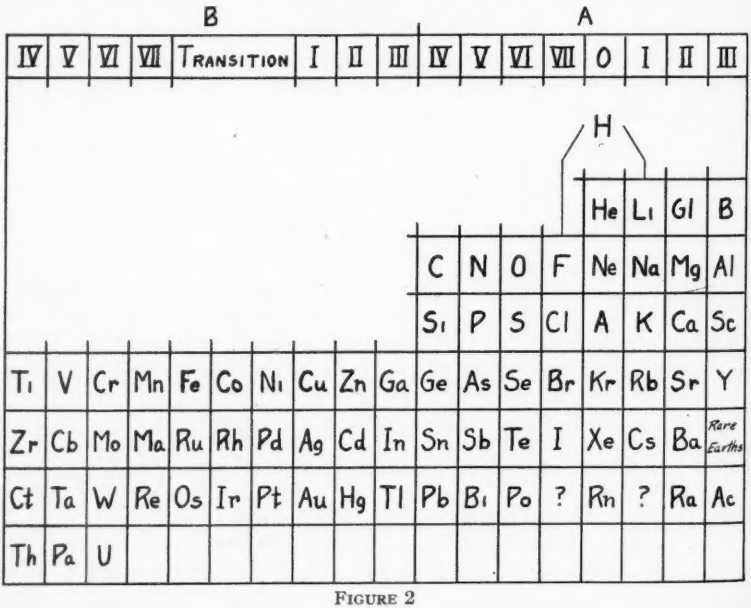
B
A
IV V VI VII TRANSITION I II III IV V VI VII 0 I II III
H
He Li Gl B
C N O F Ne Na Mg Al
Si P S Cl A K Ca Sc
Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr Rb Sr Y
Zr Cb Mo Ma Ru Rh Pd Ag Cd In Sn Sb Te I Xe Cs Ba Rare Earths
Ct Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po ? Rn ? Ra Ac
Th Pa U

FIGURE 2

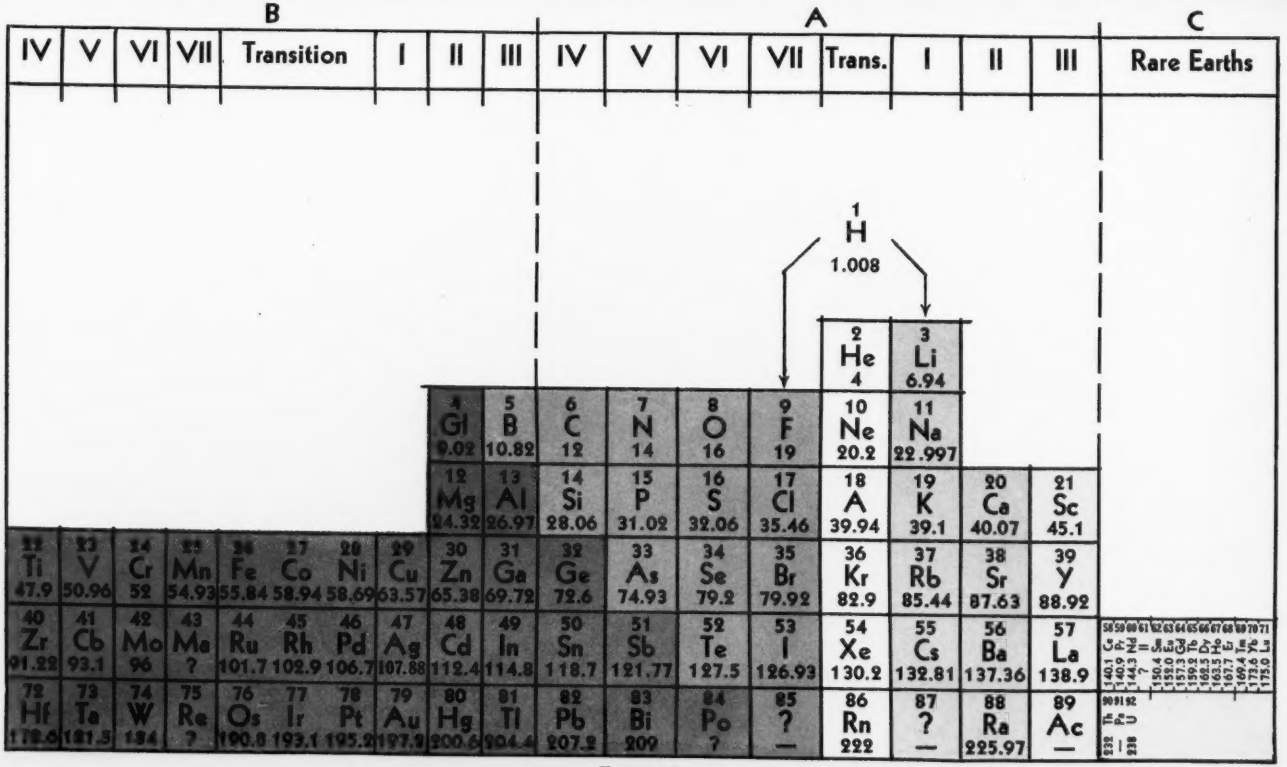
B
A
C
IV V VI VII Transition I II III IV V VI VII Trans. I II III Rare Earths
1 H 1.008
2 He 4
3 Li 6.94
4 Gl 9.02
5 B 10.82
6 C 12
7 N 14
8 O 16
9 F 19
10 Ne 20.2
11 Na 22.997
12 Mg 24.32
13 Al 26.97
14 Si 28.06
15 P 31.02
16 S 32.06
17 Cl 35.46
18 A 39.94
19 K 39.1
20 Ca 40.07
21 Sc 45.1
22 Ti 47.9
23 V 50.96
24 Cr 52
25 Mn 54.93
26 Fe 55.84
27 Co 58.94
28 Ni 58.69
29 Cu 63.57
30 Zn 65.38
31 Ga 69.72
32 Ge 72.6
33 As 74.93
34 Se 79.2
35 Br 79.92
36 Kr 82.9
37 Rb 85.44
38 Sr 87.63
39 Y 88.92
40 Zr 91.22
41 Cb 93.1
42 Mo 96
43 Ma ?
44 Ru 101.7
45 Rh 102.9
46 Pd 106.7
47 Ag 107.88
48 Cd 112.4
49 In 114.8
50 Sn 118.7
51 Sb 121.77
52 Te 127.5
53 I 126.93
54 Xe 130.2
55 Cs 132.81
56 Ba 137.36
57 La 138.9
72 Hf 178.6
73 Ta 181.5
74 W 184
75 Re ?
76 Os 190.8
77 Ir 193.1
78 Pt 195.2
79 Au 197.2
80 Hg 200.6
81 Tl 204.4
82 Pb 207.2
83 Bi 209
84 Po ?
85 ?
86 Rn 222
87 ?
88 Ra 225.97
89 Ac
90 91 92
Th Pa U
232 231 238

FIGURE 3

group VIII is called the "transition" group and serves very nicely to bridge the differences in the properties of VII B and I B. Now, the inert gas group occupies the same position between VII A and I A, and the nomenclature of Deming is used (Figure 2). To the student, the profound difference between the halogens and the alkali metals is nicely explained by his study of atomic structure and the inert gases truly occupy the "transition" position, just as the old group VIII occupies a "transition" position in the "B" groups.

IV. Now the first indicator that the beginning student learns to use is litmus. Since acids turn litmus red, the area of the chart occupied by the non-metals, the type of element that forms acids, can be colored or painted red. Similarly, the area occupied by the alkali and alkaline earth metals can be colored blue. The sole object of this scheme is to enable the student to grasp immediately the principal chemical properties of an element by noting both the group position the element occupies and the color of its background. (See Figure 3.)

Since the "B" group elements are mostly amphoteric and to distinguish still further between the "A" group type and the "B" group type, the background of the "B" groups can be painted purple. This color, resulting when red and blue are properly blended will serve to denote the amphoteric properties.

The rare earth type elements, including III A, have been colored a light shade of blue, to denote the metallic properties of this group, and will set off the group as a set of elements peculiar unto themselves as compared to the other types of elements.

V. We say that the "B" group elements are more closely related in a horizontal direction than are the "A" group elements and so it is possible to represent pictorially that fact by placing the symbols of the "B" group elements in the narrower spaces (Figure 3). Of course, this is possible in the case of the Deming modification but not in the Mendeléeff model.

VI. Looking over the chart again (Figure 2), we see that group III A occupies a position at the extreme right of the chart. Lanthanum and the fourteen rare earth elements that usually are assigned to the same space with lanthanum are in group III A. Now the 10 extra elements of the long periods (extra in that there are 18 as compared to the 8 of the short periods) are classified as "B" group elements. Why not call the rare earth elements the "C" groups? (Figure 3.)

It has been suggested that the "transition" group of the "C" groups would have to contain seven elements, corresponding to three in the "transition" B group and one in "transition" A, if the grouping should be identical with that of the "A" and "B" groups. It is the purpose of this article only to suggest this possible modification rather than to justify it.

A wall chart of this particular classification of elements has been used in connection with the elementary course in chemistry for the past three years at Doane College, and an earlier modification was used the two preceding years (*5*). This year, and last, each student has been required to make a duplicate of the chart, notebook size, with colored backgrounds and spacing as shown in this chart. This, of course, is done because this chart does not appear in the textbook. The reactions from the students toward the work in the part of the course following the study of the periodic classification and the structure of the atom has been in most cases extremely favorable. In the cases where students go on with the study of chemistry, it has been found that they use the chart as a sort of catalog of chemical and physical properties. It must be emphasized that this type of chart is not the only one presented in the course. The history of the development of the periodic classification of elements is given in the course of the lectures, and quite some little time is spent on each type of chart previously mentioned, in order that the student shall not be given a one-sided view of this particular type. In the case of the better students who are interested, it is demonstrated to them that this chart can be evolved from a helix model by cutting the spirals down the proper sides and then laying the model out flat on the table.

Finally, it should be remembered that this classification or chart will lend itself to the same "informational treatment" that Hubbard and Deming provide for their respective charts. At present the value to the beginning student of such extensive treatment as Hubbard provides, for example, is questionable in the minds of many teachers of elementary chemistry. Believing that simplicity should be the keynote of a chart intended for use by the beginner, this treatment is not made use of in this modification. There is no doubt, however, that such extensive information is desirable for the student who is making an extended study of chemistry.

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Without a historic setting for his work, a man is almost as hopeless as is the man who lacks a sense of humor.—WILLIAM WARNER BISHOP

VAPORS AND THE GAS LAWS

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The vapors of liquids at or near the boiling point occupy a smaller volume than is calculated by the simple gas laws. A simple correction, $\frac{P_c - 1.32}{P_c}$, *is applied to the gas constant to compensate for this deviation. The correction, which is derived from Berthelot's equation, has been evaluated for several of the common liquid compounds.*

. . . . . .

The physical chemist finds numerous occasions when he encounters pressure-volume-temperature relations of the vapors of compounds which are normally liquid. In vapor density methods for the determination of molecular weights, in the Clausius-Clapeyron equation for vapor pressures, in the thermodynamic computation of the ebullioscopic constants; in these and many other instances, it is necessary either to assume that the vapors of liquids follow the gas laws with sufficient exactness or to apply a correction for the deviation from the simple laws.

Of the various equations of state proposed for this purpose the simplest and most widely used is that of van der Waals, which corrects both for the attractive force between the molecules and for a lack of compressibility at high pressures. D. Berthelot (*1*) has modified the equation to express the arbitrary constants a and b in terms of the critical conditions and with the volume at the limit of compressibility equal to a quarter rather than a third of the critical volume as would be indicated by the original equation. This has been found to apply with great exactness to a wide variety of substances over a considerable range of pressures. In spite of its obvious advantages, it appears somewhat formidable to one who has never attempted it.

$$PV = RT\left[1 + \frac{9}{128} P/P_c \frac{T_c}{T}\left\{1 - 6\left(\frac{T_c^2}{T^2}\right)\right\}\right]$$

Nernst (*2*) has utilized a simpler empirical equation for the correction of vapor pressure data in the computation of the latent heat of vaporization. His equation is

$$PV = RT\,[1 - P/P_c]$$

It may be demonstrated that this form is not a correct one, but its use is much more accurate than the common practice of making no correction at all.

Inasmuch as the necessity for a correction arises most frequently in the case of a saturated vapor at the temperature of normal ebullition or near this temperature, a special form of the Nernst equation applicable to this particular case is valuable. Such a relation may be derived from the Berthelot equation.

Guldberg and Guye (*3*) have shown that the boiling point of a liquid on the absolute scale is approximately two-thirds of the critical temperature on the same scale. Assuming this ratio to be correct, we may substitute 1.5 for T_c/T in all cases and regardless of the nature of the substance. With this substitution the Berthelot equation becomes

$$PV = RT\ [1 - 1.32\ P/P_c]$$

or, when the critical pressure is expressed in atmospheres

$$PV = RT\left[\frac{P_c - 1.32}{P_c}\right]$$

The form of the equation indicates immediately the sign and the approximate magnitude of the correction. Where the critical pressure is very great, the correction is small as in the case of water vapor. On the other hand, when the critical pressure is small, the correction is rather important. To ignore the necessity for correction involves an error of 3.4% with benzene, 1.5% with alcohol, and 4% with ether. All this is readily shown by the equation proposed with none but the simplest computation.

It is apparent that as the temperature rises above the normal boiling point, the constant correction term will approach that of the Nernst equation, but at temperatures below the boiling point the constant is greater than that shown. Above or below the boiling temperature, the universality of the temperature relationship disappears and the constant of the equation becomes different for each substance.

Table I shows a comparison of the corrections to be applied; (1) calculated from the Berthelot equation, (2) from the Nernst equation, (3) the proposed equation, and (4) from the density of the saturated vapor at the temperature of normal ebullition as taken from the Chemical Rubber Co., Handbook of Chemistry and Physics. It is apparent that certain of the density data are erroneous and that the corrections, calculated from the proposed equation, are at least as accurate as the quality of the available data would require.

TABLE I

Correction to Be Applied to Volumes of Saturated Vapors at Normal Boiling Point

	Proposed Equation	*Berthelot Equation*	*Nernst Equation*	*Observed*
Benzene	0.9725	0.9658	0.9791	0.9791
Alcohol	0.9790	0.9844	0.9840	0.9739
Water	0.9932	0.9900	0.9949	0.9872
Chloroform	0.9759	0.9693	0.9818	0.9825
Ether	0.9631	0.9607	0.9721	0.9435
Methanol	0.9832	0.9814	0.9872	0.9551

As an example of the value of the correction, we may cite the calculation of the latent heat of vaporization of benzene from the vapor pressures.

Over the range from 70 to 80°C. Nernst (*4*) calculated the latent heat by the formula

$$\lambda = 1.985 \times 2.303 \frac{T_1 T_2}{T_2 - T_1} \log \frac{P_2}{P_1}$$

to be 7620 calories per mol, while the observed value is 7426 calories. Applying the correction term, $\frac{P_c - 1.32}{P_c}$, which in this case is equal to 0.9725, the calculated value is 7417 calories, in excellent agreement with the observed heat of vaporization.

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(*1*) D. BERTHELOT, "Sur les thermomètres à gaz," Gauthier-Villars, Paris, **1903.**
(*2*) NERNST, "Theoretical Chemistry," fifth edition, Macmillan & Company, Ltd., London, **1923,** p. 317.
(*3*) GULDBERG, *Z. physik. Chem.*, **5,** 374 (1890).
(*4*) NERNST, "Theoretical Chemistry," fifth edition, Macmillan & Company, Ltd., London, **1923,** p. 67.

Blight-Killed Chestnuts Salvaged by Tanning and Paper Industry. Chestnut forests now dead or dying from the blight can be salvaged twenty years hence for the tanning and paper industries, a recent report by the paper section of the Bureau of Standards of the U. S. Department of Commerce states.

Despite efforts to introduce blight-resisting trees from Asia into this country, the spread of the disease, together with the commercial exploitation of the chestnut by the tanning and paper industries, indicates the ultimate exhaustion of American chestnut forests.

The day when a shortage will be felt has been postponed by many years, however, through the discovery that dead trees can be used as a source of paper and tannin. Investigations conducted by the Bureau of Plant Industry, U. S. Department of Agriculture, have revea'ed that dead trees suffer no appreciable loss of tannin even over long periods of time. It has also been demonstrated that dead trees can be used in paper manufacture and a paperboard mill has been recently built in the worst blight-infected territory with expectations of using the trees for twenty years.

"The available information undoubtedly indicates the ultimate exhaustion of our chestnut forests," concludes the Bureau of Standards report.

"The usefulness of the dead trees as a source of paper and tannin has been demonstrated, however, and thus the tanner and paperboard producer seem assured of a supply of this cheap raw material for many years to come."—*Science Service*

New Woods Sought for Lead Pencils. The pencil wood supply near large factories is practically exhausted and the industry is now investigating the possibility of utilizing Alaska red cedar, the finest grained wood of the Northwest. Cedar wood intended for lead pencils must be soft, light yet strong, close and straight-grained, and free from defects. The older the tree the better pencil wood it makes. The wood from the heart of aged logs that have lain in deep woods for years makes admirable pencil material.

A possible substitute for cedar in lead pencils is Pacific coast myrtle. Its wood is light, straight-grained, well scented, and of good color. Both cedar and myrtle woods are immune to the effects of quick climate changes.—*Science Service*

ACIDIMETRY AND ALKALIMETRY BY THE USE OF SYMMETRICAL DIPHENYL GUANIDINE

H. H. Chakmakjian, Tufts College Medical School, Boston, Massachusetts

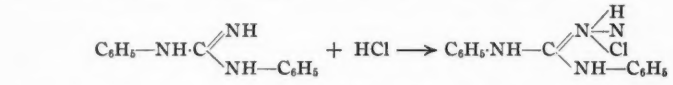
Sometimes very useful information is lost in the ever-increasing mass of chemical literature. In 1922 C. A. Carlton (*1*) published his work on symmetrical diphenyl guanidine as a reliable, easily reproducible standard for a quick titration in acidimetry and alkalimetry.

Diphenyl guanidine is an important accelerator in the vulcanization of rubber and may be obtained easily for a reasonable price.*

In the standardization of acids and alkalies use is made of chemically pure sodium bicarbonate which is heated to 350–360°C. in a sand-bath for about three hours, and after cooling about 0.5 gram sample is weighed in a weighing bottle and heated again in the sand-bath until constant weight is secured. This process means waiting for a long time before one is able to start the titration, and if any accident happens to one or more of the weighing bottles while heating, the day's work may be seriously impeded. Even if everything goes smoothly some element of doubt is left as to the accuracy of the determination. This doubt may be eliminated by checking the normality of hydrochloric acid, for instance, by a time-consuming gravimetric method such as the silver chloride method, provided the acid is freshly prepared. A three-months old sample of standard hydrochloric acid will have the same chlorine content but lower normality due to the action of the silicates in the glass container. Checking may also be done by the uses of recrystallized C.P. oxalic acid, or by electrometric titration. The safest and easiest confirmation of the normality of a given acid may be obtained by the use of diphenyl guanidine.

Diphenyl guanidine neither gains nor loses weight, and therefore it may be used to determine the normality of an acid as often as desired and in a length of time just necessary to weigh and titrate two samples, provided diphenyl guanidine has been previously purified by recrystallization from toluene.

Symmetrical diphenyl guanidine is a monoacid base, insoluble in water but soluble in alcohol and mineral acids. Evidently two phenyl radicals deprive two secondary amine radicals of their basicity and leave the middle nitrogen with double bond as a strongly basic secondary amine radical. Therefore the reaction with hydrochloric acid may be given.



The weighed sample (about one gram) is transferred to a 250-cc. beaker and dissolved in a volume of alcohol about equal to the volume of acid needed to neutralize it, using 2 drops of methyl red as indicator. The

* May be purchased from Eastman Kodak Co.

molecular weight of diphenyl guanidine being high (211.13), large quantities of it may be used in order to reduce any possible experimental error. One gram of the base will require 47.36 cc. of 0.1 *N* acid.

Another important advantage of the base is the fact that after its purification by three crystallizations the fine white crystalline substance may be kept in glass-stoppered bottles for years without any alteration. In our laboratory the purification of the base was performed in 1923, and we are still using it for our standardization with satisfaction.

The purification was carried out according to the method given by Carlton. One hundred grams of diphenyl guanidine was dissolved in 800 cc. of hot, almost boiling, toluene which was previously dried over calcium chloride and redistilled. The solution was filtered through a hot-water funnel, and the filtrate cooled with vigorous stirring or shaking under running water. The recrystallization was repeated twice more, using approximately 8 cc. of toluene for each gram of the base. The residue of the last crystallization was washed twice on a Büchner funnel with cold toluene, sucked dry, and then dried in an electric oven, first at 90°C. and finally at 120° for two hours. The yield is about 80 grams or better. Cold toluene dissolves the impurities in the base but not the base itself.

(*1*) CARLTON, *J. Am. Chem. Soc.*, **44**, 1469–74 (July, 1922).

ELECTRIC METRONOME

ELBERT C. WEAVER, BULKELEY HIGH SCHOOL, HARTFORD, CONNECTICUT

In an experiment conducted by the laboratory class as a whole it was necessary that some audible time signal be given regularly so that temperature readings could be taken at intervals of one minute. By robbing some of the electric impulse which came into the laboratory clock and putting it into the "line" side of a telegraph relay we were thus able to operate a local circuit containing a bell and a dry cell so that the desired signal was given. Incidentally, no change in the time of the accustomed "passing" bell was noticed as a result of this tampering.

Early Chinese Bronze Distinct from Western Metal. Bronze-making of the early Chinese was entirely distinct from that of the Sumerians who were probably the earliest of the Mediterranean peoples to work in the copper-tin alloy.

Analyses of early Chinese bronzes made by William F. Collins, Peiping engineer, and reported to the Institute of Metals, London, lead to this conclusion. The Chinese bronzes contained high percentages of lead, whereas the Sumerian bronze seldom contained more than one per cent of lead.

It is considered by many metallurgists that China developed metal working earlier than, and independently of, western civilization, if bronze casting originated independently. Mr. Collins thinks that it began probably in Kansu, Shensi, or Honan provinces, which are sites of the earliest cultures known in China.—*Science Service*

THE PREPARATION OF LIQUID AMMONIA AS A LABORATORY PROJECT

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The reactions and properties of liquid ammonia are often discussed in chemistry classes, but, unfortunately, an objective study of this subject is rarely undertaken. This is perhaps due primarily to the inaccessibility of liquid ammonia in sufficiently small quantities for laboratory demonstrations. Also, the liquid is difficult to handle under ordinary conditions.

In the suggested study herein described, these difficulties have been overcome. In addition, apparatus has been used which may be readily secured from equipment available in the average general chemistry laboratory. The study may be used as a project for students, as a demonstration experiment, or as a preparation in an advanced course.

Materials and Apparatus Set-Up

The essential details of apparatus required and the arrangement of it are revealed in the accompanying diagram, but a few suggestions regarding it may be of value.

The safety tube, *A*, filled with mercury to a height of 5 cm., is used to prevent an unduly high pressure being developed within the apparatus in the event that the drying tube, *F*, should become clogged.

The asbestos board, *D*, is inserted to protect the cooling chambers and to keep the flame away from the alcohol and chloroform solutions.

A straight inner tube of a condenser serves very well for the drying tube, *F*. Tubes *F* and *H* may be filled with soda lime, since this material is readily available. Other drying agents may be used (*1*).

The condensing chamber, *K*, may be made by cutting the bottom from an ether can, and fitting the end of a glass coil, *L* (the inner coil from a broken condenser is quite suitable), through the mouth by means of a closely fitting cork. By surrounding the can with sheet asbestos, the efficiency of the condenser will be increased.

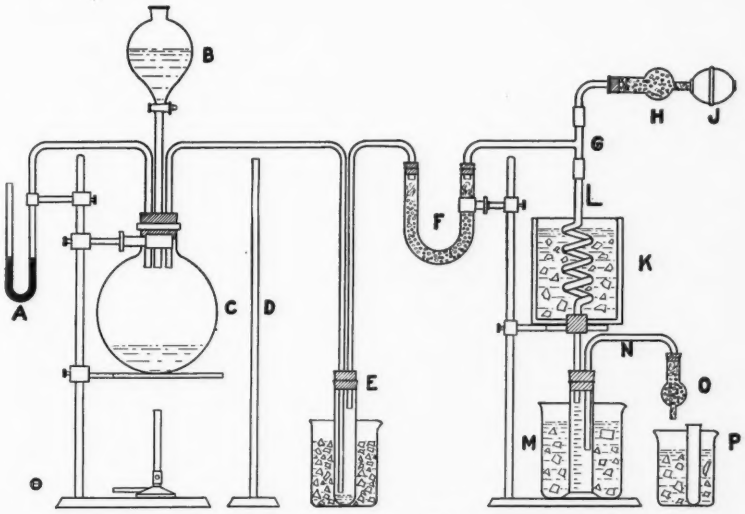
The receiving flask within the beaker, *M*, may be made by cutting the top off a graduated cylinder. The volume of liquid ammonia obtained may thus be read directly.

All connections should be air-tight and care should be taken to prevent moisture from condensing with the ammonia.

Operation

When the apparatus is assembled, ready for operation, solid ammonium chloride, sufficient to yield the quantity of liquid ammonia sought, is introduced into the reaction flask, *C*. Condenser *K* is filled with chloroform until the major portion of the coil, *L*, is submerged. Small portions of solid carbon dioxide are then slowly added to the chloroform until strong

ebullition subsides. At this point the temperature of the bath should be sufficiently reduced to freeze mercury. An excess of solid carbon dioxide is kept in condenser, *K*, throughout the reaction. Beakers *M* and *P* are filled similarly with alcohol and solid carbon dioxide. Alcohol instead of chloroform is used in *M*, since with the latter a frozen moisture, which obscures the gradations on the receiving cylinder, is produced. Beaker, *E*, is filled with a water and ice mixture.



A—Mercury safety tube
B—Dropping funnel
C—Reaction flask
D—Asbestos board
E—Ice-cooled condensing chamber for moisture
F—Drying tube, approximately 30 cm., filled with soda lime
G—T-Tube connection
H—Drying tube, filled with soda lime
J—Aspirating bulb
K—Chloroform and solid carbon dioxide cooled condensing chamber for ammonia
L—Condensing coil for ammonia gas
M—Alcohol and solid carbon dioxide cooled collecting chamber for liquid ammonia
N—Delivery tube for liquid ammonia
O—Drying tube, filled with soda lime
P—Alcohol and solid carbon dioxide cooled storage chamber for liquid ammonia

To generate the ammonia, gradually add concentrated sodium hydroxide from dropping funnel, *B*, to ammonium chloride. As the reaction proceeds, apply heat to the reaction flask, *C*, until all the ammonia is driven off. By passing the ammonia through condenser, *E*, most of the moisture is removed before the gas enters the drying tube, *F*. The ammonia is condensed while passing through the coil, *L*, and is collected in the graduated cylinder in beaker, *M*. In order to watch the progress of the volume of

ammonia being obtained, the frost which collects on the sides of the beaker, *M*, may be washed off with alcohol.

Removal and Testing of Liquid Ammonia

To remove small amounts of the liquid ammonia from the cylinder, lower tube, *N*, until the end is well below the surface of the liquid, place the aspirating bulb, *J*, on the drying tube, *H*, and remove drying tube, *O*. Aspirate the liquid into clean dry test tubes immersed in the bath, *P*, of alcohol and solid carbon dioxide. (Tight-fitting corks should be provided to close the tubes immediately.) After aspiration, drying tube, *O*, should be replaced to prevent moisture entering the receiving cylinder.*

The reactions of liquid ammonia may be demonstrated as described in previous issues of the JOURNAL OF CHEMICAL EDUCATION (*2*).

From four mols of ammonium chloride, 82 cc. of liquid ammonia, which represents a 75% yield, were obtained.

After the apparatus has been set up, sufficient liquid ammonia for the demonstration of several reactions may be obtained easily within an hour.

Objectives

Some of the objectives brought to the attention of the students by a study of this project are:

1. Study of the reactions and properties of liquid ammonia.
2. Observations at lower than ordinary temperatures.
3. Practice in the calculation of yield.
4. Study of liquid ammonia in refrigeration.
5. Separation of a gas from a liquid.
6. Study of the properties of carbon dioxide.
7. Liquefaction of other gases.
8. General review of properties of gases.

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(*1*) COOPER AND HENSHAW, "Dehydrating Ammonia Vapors," *Chem. Abstr.*, **22,** 1018 (Mar. 20, 1928); COOPER, HENSHAW, AND W. C. HOLMES & CO., LTD., "Separating Water Vapor from Ammonia," *ibid.*, **22,** 1833 (May 20, 1928); SMITS, SWART, AND BRUIN, "The Influence of Intensive Drying on Inner Equilibria," *ibid.*, **24,** 2348 (May 20, 1930); "Activated Alumina," J. CHEM. EDUC., **7,** 2989 (Dec., 1930).

(*2*) JOHNSON AND FERNELIUS, "Liquid Ammonia as a Solvent and the Ammonia System of Compounds. V. The Properties of Solutions of Metallic Compounds in Liquid Ammonia," J. CHEM. EDUC., **7,** 981–99 (May, 1930).

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* Any suitable flask may be substituted for the graduate cylinder, and the liquid ammonia may be poured out rather than aspirated without taking up too much moisture to interfere with the reactions to be demonstrated.

AN EQUILIBRIUM EXPERIMENT FOR AN INTRODUCTORY LABORATORY COURSE IN PHYSICAL CHEMISTRY*

E. J. SHAW AND MARY ELIZABETH HYDE, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS

The need for a satisfactory equilibrium experiment for class use has been felt for some time. The most suitable reaction appears to be that of silver with ferric ion to give silver ion and ferrous ion. Equilibrium may readily be approached from either side, and the time required is such that experiments by different classes may be carried out on successive days using the same apparatus. The result obtained may be checked by a measurement of the e. m. f. of the cell.

$Ag,\ AgNO_3,\ KNO_3$ *(sat. sol.),* $Fe(NO_3)_2\ Fe(NO_3)_3,\ Pt.$

The temperature coefficient of this cell has been determined so that the results obtained by the two methods may be compared at the same temperature.

. . . . . .

Physical chemistry stresses the importance of equilibrium from a theoretical viewpoint. However, none of the equilibrium experiments developed up to the present time, has fulfilled the requirements imposed at this laboratory. There is a dearth of reactions whose equilibrium concentrations are such as to permit accurate analytical determinations, and which come to equilibrium within a reasonable time. The reaction,

$$Ag + Fe(NO_3)_3 \rightleftharpoons AgNO_3 + Fe(NO_3)_2,$$

investigated by Noyes and Brann (*1*), appears to fulfil the necessary requirements. Popoff, Fleharty, and Hanson (*2*) have recently determined the equilibrium of the reaction

$$2Hg + 2Fe(ClO_4)_3 \rightleftharpoons Hg_2(ClO_4)_2 + 2Fe(ClO_4)_2;$$

this reaction, though perhaps more satisfactory because of the absence of interfering reactions, cannot be adapted for class use on account of the length of time required to reach equilibrium.

The equilibrium constant was determined both analytically and electrometrically. In the analytical method the end-point was approached from both sides of the reaction.

Experimental

The experiments were carried out in 125-cc. glass-stoppered bottles sealed with beeswax, which was found more satisfactory than paraffin. In each bottle was placed 2.5 g. of finely divided silver and 100 cc. of ferric nitrate of the desired concentration, three concentrations being used. In order to obtain equilibrium from the ferrous-silver ion side, one set of bottles was heated to 55°C. in a water-bath for one half hour. Then all the bottles were placed in a thermostat which was kept at 24.7 ± 0.1°C. and

* This communication is a portion of the thesis submitted by Miss Hyde in partial fulfilment of the requirements for the degree of Bachelor of Science in Chemistry at the University of Illinois.

provided with means of agitation. The bottles were kept in the thermostat for twenty hours. At the end of this time they were taken out and analyzed and the equilibrium constant determined.

The silver for the experiment was prepared in the following way: 85 per cent formic acid, to which about one-third of its volume of water had been added, was neutralized with ammonium hydroxide. The ammonium formate was then heated to boiling. A fairly concentrated silver nitrate solution was also heated to boiling. The ammonium formate was then slowly added in small amounts, great care being necessary because of the violence of the reaction. After the reaction was complete the silver was filtered off, washed thoroughly, and dried by suction.

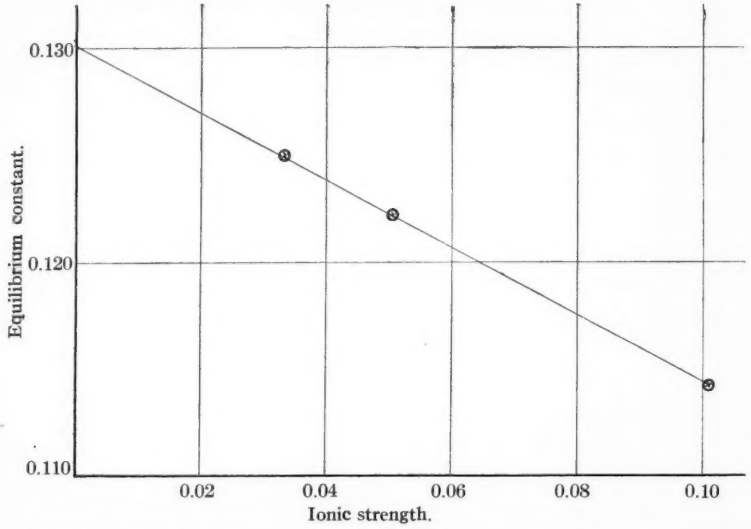

FIGURE 1.—EXTRAPOLATION OF EQUILIBRIUM CONSTANT TO ZERO IONIC STRENGTH

Mallinckrodt C.P. $Fe(NO_3)_3 \cdot 9H_2O$ was used in the preparation of the ferric nitrate solutions. The ferric nitrate was dissolved in 0.0125 *N* nitric acid solution in order to prevent hydrolysis.

All of the analyses were carried out volumetrically. Total iron was determined by converting the nitrate into the sulfate and proceeding in the usual manner. The equilibrium mixture was titrated with potassium permanganate solution to determine the ferrous iron and with potassium thiocyanate solution to determine the concentration of the silver ion, the iron present acting as an indicator. Slight acidification with sulfuric acid and heating prevented the obscuring of the end-point due to precipitation of ferric hydroxide. The same sample was used in the determination of

both ferrous ion and silver ion concentrations. The ferric iron was determined by difference.

Table I shows the change in the equilibrium constant with a change in concentration. In order to obtain a true equilibrium constant it is necessary to extrapolate to zero concentration. This may best be done by plotting the equilibrium constant against the ionic strength of the solution and extrapolating to zero ionic strength (*3*). Figure 1 shows the results. From Figure 1 the extrapolated value of the equilibrium constant is 0.130.

TABLE I

Total Fe, m	K_a	K_b	M	Total Fe, m	K_a	K_b	M	Total Fe, m	K_a	K_b	M
.00915	.125	.126	.0335	.0135	.1223	.1223	.0506	.0256	.115	.113	.1027
.00915	.1255	.1265	.0335	.0135	.1223	.1223	.0506	.0254	.115	.114	.1024

K_a, K_b represent the constant from the silver-ferric iron and the silver ion-ferrous iron sides, respectively.

At this university the class was given instructions and placed the silver in the bottles and labeled them during one laboratory period. Twenty hours before the beginning of the succeeding laboratory period the bottles were placed in the thermostat. During the usual laboratory period the titrations were carried out.

For the electrometric work the cell,

$$Ag,\ AgNO_3,\ KNO_3\ (sat.),\ Fe(NO_3)_2,\ Fe(NO_3)_3,\ Pt$$

was used. It was assumed that the saturated potassium nitrate solution reduced the liquid junction potential to a negligible amount.

The ferric nitrate solution for this part of the experiment was prepared as in the analytical part. The silver nitrate solution was prepared by direct weighing using a good grade of silver nitrate. The ferrous nitrate solution was prepared by adding a boiling solution of barium nitrate to a boiling solution of ferrous sulfate until the reaction was complete, and then the barium sulfate was rapidly filtered off. The ferrous nitrate was protected from the air by a layer of stanolind.

The determination was carried out as follows. The solutions of ferric and ferrous nitrate were mixed in equal amounts and the mixture was placed in a half-cell similar to that used for the calomel half-cell. In another half-cell was placed the silver nitrate in contact with a polished silver electrode. The side arms of both half-cells dipped into a beaker containing a saturated potassium nitrate solution. Popoff and Kunz (*4*) found, in determining the potential of the ferric-ferrous electrode, that it required some time for an electrode of this type to reach equilibrium. It was found that from about one and a half to two and a half hours after the cell was set up it gave a steady potential and this value was taken as the potential of the cell at that particular temperature. Table II shows a characteristic change of the potential of the cell with time.

TABLE II

Time (Min.)	*Voltage*
0	Cell set up
15	0.0055
60	0.0490
75	0.0490
90	0.0495
105	0.0495
120	0.0495
130	0.0495
150	0.0495
270	0.0336
330	0.0320

From the observed value of the electromotive force of the cell, by means of the equation,

$$E - E^\circ = RT\ ln\ \frac{A_{Fe^{++}} + A_{Ag^+}}{A_{Fe^{+++}}},$$

E° for the cell may be obtained. Assuming the activity coefficients given in Lewis and Randall's "Thermodynamics" (*5*), the equilibrium constant may be determined. As is seen from the table the ionic strength of the solution must be 0.1 M or less. The average value of the equilibrium constant obtained electrometrically is 0.114. Popoff's recent E° value for the ferric-ferrous electrode, together with the E° for the silver-silver ion electrode gives a value of 0.1306 for the equilibrium constant.

Determinations of the electromotive force of the cell at 14°, 25°, and 31°C. give the average temperature coefficient of the cell as -0.000409 volt per degree. Using this value, the observed electromotive force may be corrected to the temperature at which the analytical determination was carried out.

Conclusions

A procedure has been devised whereby a class meeting one three-hour laboratory period per week may perform an equilibrium experiment in two class periods and check the results electrometrically in a third.

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(*3*) LEWIS AND RANDALL, "Thermodynamics," McGraw-Hill Book Co., Inc., New York City, **1923**, p. 374.

(*4*) POPOFF, S., AND KUNZ, "Oxidation-Reduction Potentials. I. Ferric-Ferrous Electrode," *J. Am. Chem. Soc.*, **51**, 382–94 (1929).

(*5*) LEWIS AND RANDALL, *loc. cit.*, p. 382.

A DEVICE FOR DELIVERING A STREAM OF WATER AT A CONSTANT TEMPERATURE

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Recently it was desired to deliver a fairly rapid stream of water at 55°C. by means of the apparatus shown in Figure 1. The regulating device was a gas thermostat of the type shown in Figure 2. In this apparatus, when the water in the reservoir (*a*, Figure 1) rises above 55°, the mercury rises in the

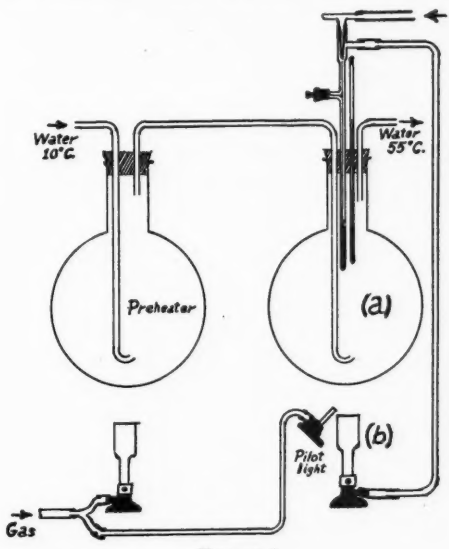

FIGURE 1

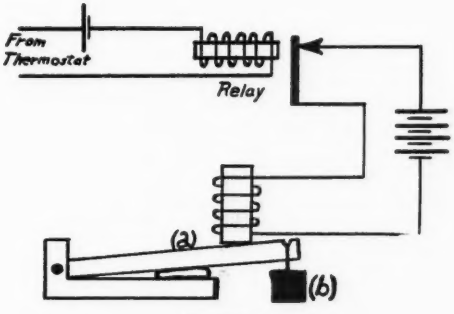

FIGURE 3

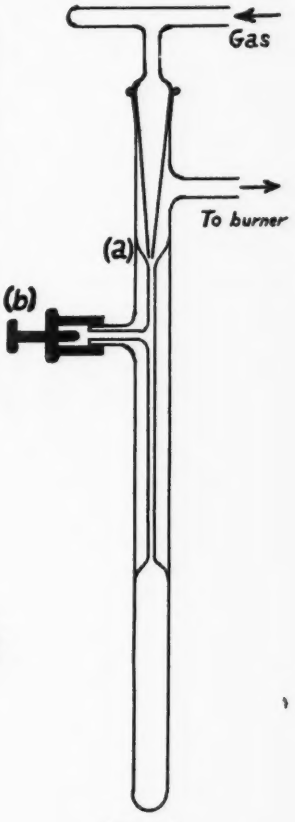

FIGURE 2

capillary tube, closing the orifice (*a*, Figure 2), thus shutting off the supply of gas to the burner. However, it was found that the orifice in this type of apparatus was so small as to deliver a supply of gas too small to have much

heating effect on the large volume of water used, and it was almost impossible to regulate the supply of water so that this small flame would keep it at exactly 55°.

The following device, which proved to be very satisfactory, was then resorted to. The gas thermostat was easily converted into an electric thermostat by inserting a contact wire in place of the orifice tube (*a*), and making the other contact at (*b*). The tube leading from the gas supply to the burner (*b*, Figure 1) was then cut and a short piece of rubber tubing taken from the end of a toy balloon was inserted between the two ends. This length of soft tubing was fastened in place under the iron lever (*a*, Figure 3).

The lever is held up by the magnet coil, allowing the gas to flow freely through the tube. When the water in the reservoir reaches a temperature of 55°, the thermostat circuit is closed, the secondary circuit is opened by means of a relay, and the weight at (*b*) pulls the lever down, pressing against the rubber tube and thus shutting off the supply of gas. When the temperature falls below 55° the secondary circuit is then closed, and the magnet pulls the lever up, allowing gas to flow through the tube.

This apparatus was found to deliver a much greater volume of gas than the gas thermostat, and therefore proved to be much more satisfactory.

Making Grass Grow Earlier. One of the most interesting examples of the application of science to agricultural methods is the intensification of grass-land farming. This is gradually bringing about something of a revolution in British agriculture, since the realization of its value has coincided with the great turnover from agriculture proper to grass. The arable acreage in Great Britain between 1918 and 1930 decreased by over 2½ million acres. Actually the year 1929–30 saw a decrease of no less than 114 thousand acres in England and Wales and about 19 thousand in Scotland.

Experiments have now been carried out at the I. C. I. agricultural research station at Jealott's Hill which show that an enormous saving in labor and expense can be effected by treating grass growing scientifically. The grass must be so treated that it starts to grow earlier in the year. Normally, growth starts in May, but by the application of nitrogenous fertilizers it is possible to start a healthy natural growth by March. The saving to the farmer by this early grass is estimated at no less than £2 per head in cattle feeding costs between April and October. Proof of the value of the practice is found in the increase of acres of grass under intensive cultivation. The acreage in England and Scotland has increased from a mere 75 acres in 1926, 925 in 1927, 27,000 in 1928, 61,000 in 1929, to nearly 200,000 in 1930.

Some of the fertilizers used, more particularly sulfate of ammonia, are made synthetically, the raw materials being coal, water, air, and calcium sulfate. Such progress has been made with the bulk production of these fertilizers at Billingham, and elsewhere, that they have been brought well within the means of the smallest farmer and even of the small holder.—*Chem. Age*

A STUDY OF THE RELIABILITY OF EXAMINATION MARKS IN GENERAL CHEMISTRY*,**

T. B. HOMAN AND HAROLD C. HODGE,† OTTAWA UNIVERSITY, OTTAWA, KANSAS

The median paper in a first mid-term examination in general chemistry was mimeographed, question and answer, and sent to one hundred college and university instructors of general chemistry. Sixty-four graded lists were returned. The scores on each question and on the whole examination were tabulated and analyzed. A wide variation was found in the evaluation of each question and of the total score.

. . . . . .

After a study of several articles (*1*) on the reliability of school marks in such studies as algebra, English, etc., it was suggested that a study be made of marks in chemistry. The median paper in the first mid-term examination in general chemistry was chosen as the paper for the study. The entire paper, question and answer, was mimeographed and sent to one hundred university and college instructors in general chemistry. These men were asked to grade the paper as though it were their own student's and to rate it on the basis of one hundred per cent. Sixty-four instructors returned graded replies. In some instances two men in the same college graded the paper without either having any knowledge of the marks of the other until after the paper was graded. It is interesting to note that on one such occasion there was a difference of fourteen in the marks of the two instructors. Some of the men grading made notes to the effect that knowing the student might make some difference in the grade given; another, that the whole study was more or less a joke as chemistry was too much of an exact science to make much difference, and implying that all the grades given would be similar in their evaluation regardless of the number of instructors grading the paper.

Each question and answer together with the distribution table and chart are taken in their regular order.

1. *Q.* How would you distinguish a chemical from a physical change?
   A. A physical change does not alter the properties. A chemical change causes a disruption in the substance and makes the change permanent while a physical change only changes color or density and will go back to its original state.

The distribution table (Table I) for Problem No. 1 has a range from one per cent to ten per cent and with the exception of two peaks (Figure 1) the distribution is more or less general. The equality of the two peaks is

* Presented before the Division of Chemistry of the A. C. S. at Indianapolis, Indiana, March 31, 1931.

** BERTHA WILSON and MARGARET JOHNSON, members of the class in Tests and Measurements, worked out this study under the direction of DR. T. B. HOMAN, Head of the Department of Education and Psychology.

† Now at the University of Rochester, Rochester, New York.

evident, as well as the relative spread in the evaluation of the problem, eleven people giving it perfect while fourteen gave it one-half.

Problem No. 2 is more or less iron-bound in its answer as there should be but one kinetic molecular theory. However, in the distribution table (Table II) following Problem No. 2 we find the entire range of per cents including zero and ten. We have also evidence of so-called exactness in the one-half per cents given. The average instructor is more or less inclined to consider the one-half per cent on the decile rating for a problem as either an absurdity or as heart balm for the student. In the distribution graph

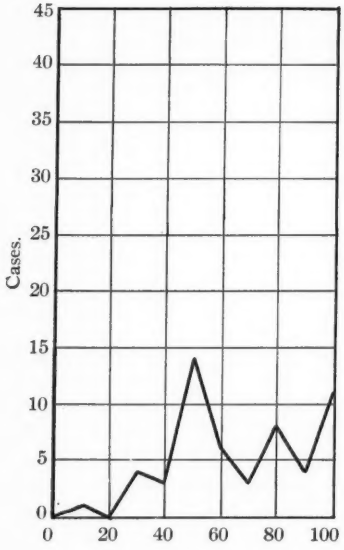

FIGURE 1

TABLE I

Distribution of Scores on Problem 1

Per Cent Score	*No. Cases*
0	0
1	1
2	0
3	4
4	3
5	14
6	6
7	5
8	8
9	4
10	11

2. *Q.* State briefly the kinetic molecular theory.
   A. Molecules of a gas travel in a straight line and at all velocities. They bounce back with the same force as they strike.

(Figure 2) we find but one peak at which sixteen instructors graded the paper five per cent.

Problem No. 3 gives us another study that would lead to a definite answer. But not so in the minds of the men grading the paper for we find (Table III) a range of two to six with the peak of the distribution (Figure 3) at three, twenty-nine instructors so grading.

Problem No. 4 shows a little more originality on the part of the pupil or possibly a shortage in the command of English. On Problem 4 (Table IV) we have a range of two to ten in percentile scores, three people grading the paper two and one person grading it perfect. Again we have the nice discrimination of one-fourth of a per cent, which has been previously commented upon.

TABLE II

Distribution of Scores on Problem 2

Per Cent Score	*No. Cases*
0	2
1	1
2	2
$2^1/_2$	1
3	7
4	7
$4^1/_2$	1
5	16
6	7
7	4
8	5
9	1
10	2

3. *Q.* Give 4 equations representing the preparation of oxygen.

   A. $2HgO = 2Hg + O_2$; $KCl + MnO_3 = KMnO + O_2$; $2BaO = 2Ba + O_2$.

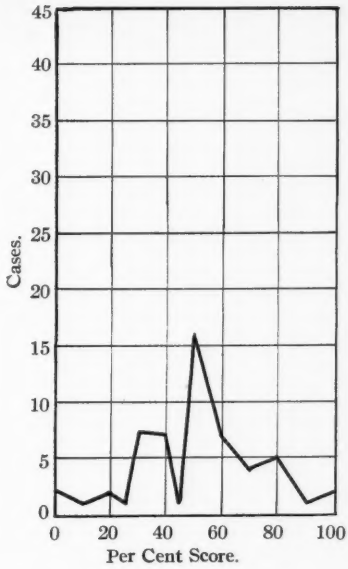

FIGURE 2

TABLE III

Distribution of Scores on Problem 3

Per Cent Score	*No. Cases*
0	0
1	0
2	4
$2^1/_3$	1
$2^1/_2$	10
3	29
3.3	1
4	8
5	2
6	1
7	0
8	0
9	0
10	0

4. *Q.* Define: element, compound, molecule, atom, catalyst.

   A. An element is that part of a substance that cannot be changed by an ordinary chemical process. A compound is a mixture of substances that has undergone a chemical change. An atom is the smallest known particle. A catalyst is a substance used to speed up or retard a reaction, without itself being changed.

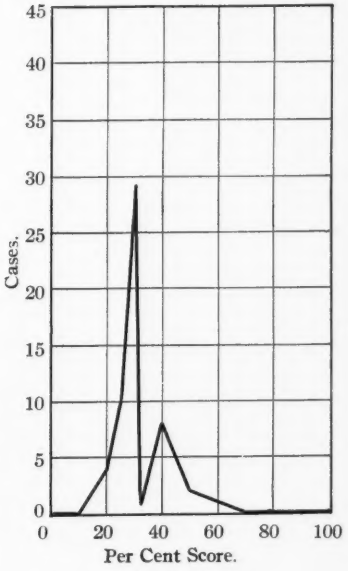

FIGURE 3

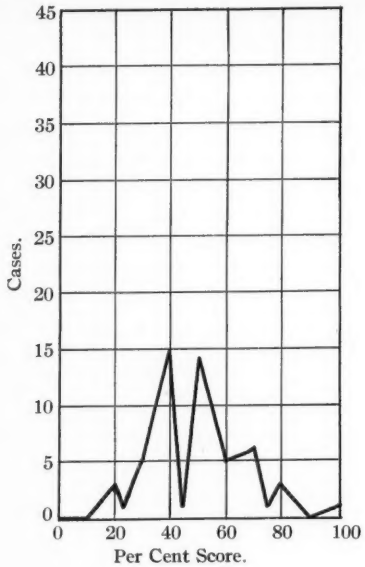

FIGURE 4

TABLE IV

Distribution of Scores on Problem 4

Per Cent Score	*No. Cases*
0	0
1	0
2	3
$2^1/_4$	1
3	5
4	15
$4^1/_2$	1
5	14
6	6
7	6
$7^1/_2$	1
8	3
9	0
10	1

5. *Q.* Water is 11.12% hydrogen. What is the combining weight of hydrogen?

A. $\frac{11.12}{16} = \frac{x}{8}$

$x = 5.56$ combining weight of hydrogen.

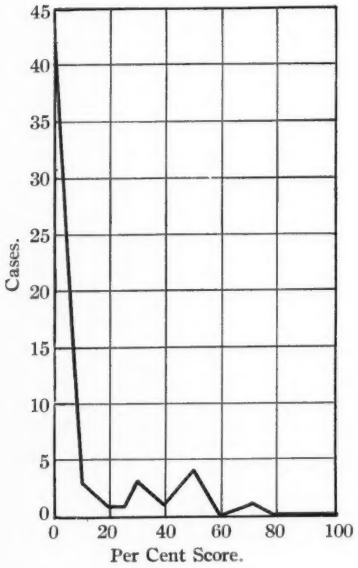

FIGURE 5

TABLE V

Distribution of Scores on Problem 5

Per Cent Score	*No. Cases*
0	42
1	3
2	1
$2^1/_2$	1
3	3
4	1
5	4
6	0
7	1
8	0
9	0
10	0

6. *Q.* What is the percentage of composition of carbon dioxide?

A. CO_3

$C = 12$

$O = 16$

$O_3 = 48$

$\frac{12}{60} = 20\%$ C

$\frac{48}{60} = 80\%$ O_2

Problem 5 (Table V) shows a scattering of fourteen grades from one to seven. Forty-two of the instructors gave the answer zero. The graph (Figure 5) for the scores on this problem gives a unique profile.

Again in Problem No. 6 we find a problem that admits of but one correct answer; however, the distribution table (Table VI) has a different story to tell, as the instructors' grades lie over the entire curve from zero to ten in a percentile scale, thirteen giving the problem zero, sixteen giving five per cent, seven giving seven per cent, and four giving ten per cent.

Inasmuch as there were nine parts to problem 7 and three of them obviously wrong, it is of interest to note a range in our percentile scores of from

TABLE VI

Distribution of Scores on Problem 6

Per Cent Score	*No. Cases*
0	13
1	0
2	3
3	3
4	4
5	16
6	2
7	7
8	3
9	1
10	4

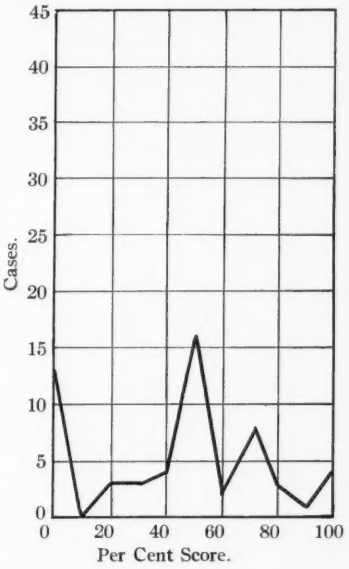

FIGURE 6

7. *Q.* Write the symbols for the following: aluminum, chlorine, copper, iron, lead, magnesium, mercury, phosphorus, sodium.

A.

Aluminum	Al
Chlorine	Ch
Copper	Cu
Iron	Fe
Lead	Pb
Magnesium	Mn
Mercury	Hg
Phosphorus	P
Sodium	So

five to eight. Seven of the instructors graded the problem six, seven graded it six and six-tenths, and thirty-five disregarded the small fractional difference and graded the problem seven.

There is considerable variation in the evaluation of the answer as the distribution table (Table VIII) shows sixteen instructors giving the problem zero, thirteen grading it five, nine grading it seven, and three grading it eight.

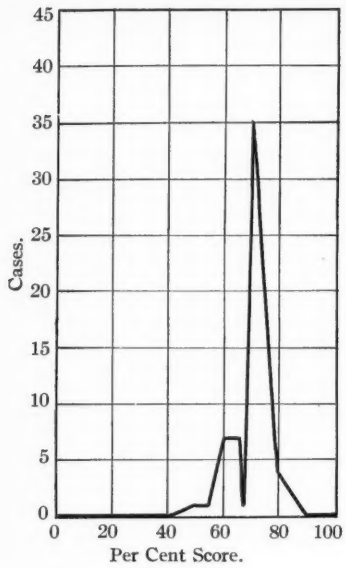

FIGURE 7

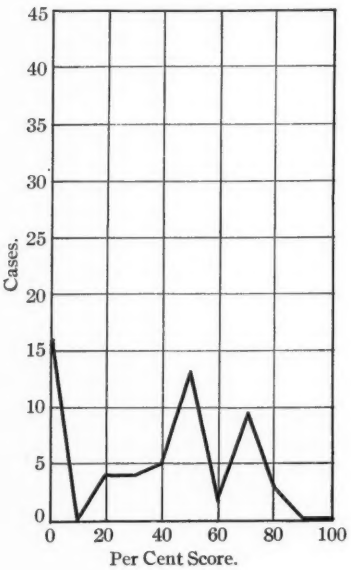

FIGURE 8

TABLE VII

Distribution of Scores on Problem 7

Per Cent Score	*No. Cases*
0	0
1	0
2	0
3	0
4	0
5	1
$5^1/_2$	1
6	7
6.6	7
6.7	1
7	35
8	4
9	0
10	0

8. *Q.* 15 cc. of oxygen at 750 mm. and 25°C. will occupy what volume at standard temperature and pressure?

A. 15 cc. of O_2 S. T. P. = 0° 760 mm.

750 mm. 273° abs.

22°C. T

$$\frac{PV}{T} = \frac{P_1V_1}{T}$$

$$\frac{750.15}{251} = \frac{760 \cdot V}{273}$$

$$(750.15)273 = 760V \cdot 251$$

$V = 16.7$ at S. T. P.

TABLE VIII

Distribution of Scores on Problem 8

Per Cent Score	*No. Cases*
0	16
1	0
2	4
3	4
4	5
5	13
6	2
7	9
8	3
9	0
10	0

9. *Q.* Discuss the uses of oxygen.

A. No answer.

10. *Q.* How many grams of Fe may be obtained from 1000 g. FeS?
A. No answer.

No reason was offered by the student for this lack of answers to questions 9 and 10. The unanswered problems introduced another uncertainty in the calculation of the total grade.

The distribution of the scores as given by the sixty-four instructors (Table IX) shows the lowest total, twenty-two per cent, and the highest total, fifty-seven per cent, with a decided scattering of the scores between these marks. The distribution of the total grades (Figure 9) gives a decidedly rough curve showing a wide range of grades when various instructors grade the same material.

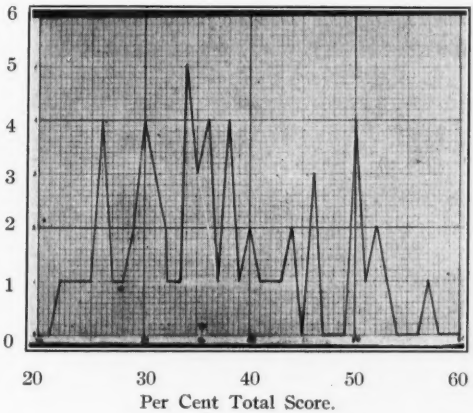

FIGURE 9

TABLE IX

Distribution Table of the Total Scores

Per Cent Score	*No. Cases*	*Per Cent Score*	*No. Cases*
22	1	40	2
23	1	41	1
24	1	42	1
25	1	43	1
26	4	44	2
27	1	44½	1
28	1	45	0
29	2	46	3
30	4	47	0
31	3	48	0
32	2	49	0
32½	1	50	4
33	1	51	1
33⅚	1	52	1
34	5	53	1
36	3	54	0
37	1	55	0
38	4	56	0
39	1	57	1

One or two graded lists had the comment that the set of questions submitted was not a good chemistry test. Quite a number of the instructors grading these papers asked why ten instead of nine parts could not have been used in question 7, leading an investigator to infer that the examination should be made principally for the ease of the examiner. One questions as to whether it would not be better to have two grades—*Pass* or *Fail*. Such an estimation would be as accurate as the difference of one-tenth of one per cent given in one of the distribution tables.

Literature Cited

(*1*) STARCH, *Science*, **38**, 630 (1913); *School & Society*, **2**, 242 (1915).

Soil on Mountain Tops More Acid than in Valleys. The higher the sourer, seems to be the rule regarding soil reactions. Confirming by researches in the richest forest region in eastern North America the observations of other investigators in various parts of the world, Dr. Stanley A. Cain of Butler University has collected a considerable series of data from the Great Smoky Mountains region in Tennessee and North Carolina, which is to be developed as the greatest of the U. S. National Parks in the East.

Starting with a moderate degree of acidity in the valleys, Dr. Cain found that the soil became more and more sour as he climbed the mountains, reaching the summits and the highest acid concentrations at the same time. The soil reaction was correlated with different types of vegetation: beech and oak-chestnut forests in the lowlands, laurel "slicks" and other heath types, together with pine woods on the middle slopes, and at the higher elevations thick growths of spruce trees standing in a deep carpet of sphagnum moss. The most acid soil was found beneath the "heath balds" that crown some of the mountains.

Many factors conspire to make acid soil in the Great Smokies region. The underlying rocks are geologically very old, of types that weather into non-alkaline soil. There is a great deal of rain and low evaporation rates, which tends to keep the ground wet all the time. The growth of dense vegetation is favored by a mild climate, yet the temperature is low enough so that fallen leaves and dead moss decay very slowly. All these factors tend to have a cumulative effect, producing a highly developed, beautiful but botanically very peculiar, type of vegetation.—*Science Service*

Magnetism Reveals Differences in Steel. Magnetism will detect differences in hardness of otherwise similar bars of steel, it was revealed in a report made by Haakon Styri of Philadelphia to a recent meeting of the American Society for Testing Materials.

Steel bars that test magnetically the same before heat treatment will test magnetically the same afterward, Mr. Styri said, provided no differences in hardness or impact strength are brought about during the heating and quenching processes. Mr. Styri's method of testing is to place the steel bars in a magnetic field and note whether the steel would make a good core for an electromagnet.

Former methods of testing uniformity in steel hardness, according to the report, have required mechanical means which involve partial destruction of the steel, whereas the testing of the steel's magnetic properties does not have this disadvantage.—*Science Service*

STATUS OF CHEMICAL EDUCATION IN UTAH SENIOR HIGH SCHOOLS*

HUGH W. PETERSON, BRIGHAM YOUNG UNIVERSITY, PROVO, UTAH

A report of a questionnaire study indicating the prevailing conditions and practices in chemical education in Utah Senior High Schools. The proportion of students receiving chemistry instruction, the training and experience of teachers, the subjects the teachers teach, the cost of chemical education, administration of supplies and laboratory work, the teachers' problems and how a university might aid the high-school chemistry teachers in their work, are phases of the subject surveyed.

. . . . . .

The purpose of this study is to obtain answers to the following questions regarding chemical education in Utah High Schools:

(1) How generally is chemistry being studied?

(2) What has been the academic training of the teachers in chemistry, and in related fields?

(3) How old, how experienced, and how recently trained, are the teachers?

(4) What other subjects do chemistry teachers teach?

(5) Where were the teachers trained?

(6) How generally are more or less professional journals used by teachers?

(7) What is the cost of chemical education?

(8) What are the prevailing arrangements regarding laboratory fees, breakage deposits, length of laboratory periods, administration of supplies?

(9) What are some of the problems confronting the chemistry teachers in their work?

(10) How can a university aid in high-school chemical education?

The method used was the questionnaire method, which, in spite of its limitations, appeared to be the only practical way of getting the needed information. A questionnaire was sent to the chemistry teacher at each of the high schools, both public and private, which is listed by the State Department of Education, with a request that the questions be answered and returned.

Data from high schools which are operated in connection with colleges was eliminated, because of the inability to separate the college facilities from those of the high school.

Number of questionnaires sent out (excluding the schools just noted)	64
Number of questionnaires returned	50 (81.6%)
Number of schools teaching chemistry of those answering	42 (84%)
Number of schools not teaching chemistry of those answering	8 (16%)
Total number of senior high-school students in the 42 high schools	16,686
Total number of students in chemistry in 42 high schools	2,329 (14%)

* Paper given before the Utah Academy of Sciences, May 9, 1931.

The schools were grouped arbitrarily into three groups: (1) schools with enrolments of 200 or fewer students; (2) schools with enrolments between 200 and 500; (3) schools with enrolments over 500, in the tenth, eleventh, and twelfth grades.

TABLE I

Enrolment in Chemistry According to Size of School

Per Cent of Enrolment Taking Chemistry	*No. of Schools below 200 2068 Total Students 370 in Chemistry*	*No. of Schools between 200–500 4264 Total Students, 793 in Chemistry*	*No. of Schools above 500 10,354 Total Students, 1166 in Chemistry*
1–5	1	0	1
6–10	2	0	5
11–15	2	4	1
16–20	5	5	2
21–25	3	3	0
26–30	2	2	2
Above 30	2	0	0
Per cent of totals.	17.9	18.5	11.3

Nine of the 17 schools, with enrolments below 200 students, offer chemistry in alternate years, while one of the 14 schools of 200–500 enrolment, alternates. In schools giving chemistry in alternate years, the chemistry enrolment was divided by 2 to get the number enrolled per year.

It will be noted in Table I that the per cent of the high-school enrolment studying chemistry is considerably smaller in the large high schools than in the smaller ones. This is probably due to an enriched curriculum in the larger schools.

TABLE II

Undergraduate Majors of Chemistry Teachers (39 Teachers)

Undergraduate Major	*No. of Teachers*	*Per Cent*
Chemistry	15	38.4
Physics, Mathematics, Science	10	25.6
Agriculture, Biological Sciences	8	20.5
Education, Psychology, Physical Education, English, Mechanic Arts	6	15.4

It appears that about five-sixths of the chemistry teachers majored in one of the more or less related fields, and that about one-sixth majored in quite unrelated fields.

TABLE III

Chemistry Courses Studied by Chemistry Teachers (42 Teachers)

Courses Studied	*No. of Teachers*	*Per Cent*
General or inorganic, only	1	2.38
General and organic, only	4	9.55
General, qualitative, quantitative, organic	4	9.55
Organic	34	81
Physical	14	33.3
Biological	9	21.4
Industrial	13	31

Table III shows the courses which have been studied, to some degree, by the teachers. There is a wide range in the number of courses, varying between one course and all the courses indicated. This suggests one cause of the variation seen in college classes in chemistry.

TABLE IV

Distribution of Teachers According to Chemistry Credits (42 Teachers)

No. Quarter Hours Credit in Chemistry, Including Graduate Credit	*No. of Teachers*	*Per Cent*
10 or fewer	2	4.76
11–15	3	7.15
16–25	11	26.2
26–35	7	16.7
36–45	10	23.8
46–55	2	4.76
56–75	3	7.15
76–95	1	2.38
96–105	2	4.76
Above 105	1	2.38

Table IV shows that about 12% of the teachers have 15 or fewer quarter hours credit, and it will be noted that the median is about 33 credits. The range is very wide. This, probably, has an effect on the quality of the courses given by the teachers.

TABLE V

Institutions Which Furnished Teachers of Chemistry (42 Teachers)

Institution	*Number of Teachers*	*Per Cent*
Utah State A. C.	21	50
University of Utah	8	19
Brigham Young University	7	16.7
Colleges outside of Utah	6	14.3

About six-sevenths of the teachers of chemistry in Utah schools were trained in Utah colleges, and half of all the teachers are graduates of the Utah State Agricultural College.

TABLE VI

Teaching Experience (42 Chemistry Teachers)

Years Experience	*Total Experience*		*Chemistry Experience*		*In Present H. S.*	
	Teachers	*Per Cent*	*Teachers*	*Per Cent*	*Teachers*	*Per Cent*
1 year	3	7.15	8	19	6	14.3
2 years	2	4.8	3	7.15	4	9.6
3–5 years	5	11.8	14	33.2	14	33.2
5–10 years	13	31	9	21.2	9	21.2
10–15 years	13	31	6	14.3	7	16.7
16 or over	6	14.3	2	4.8	2	4.8

Table VI shows that about 7% of the teachers of chemistry are having their first year of teaching experience, and that the teachers have, in

general, had considerable experience. About one-fifth of the teachers are teaching chemistry for the first time, and one-seventh are teaching in their present school for the first time.

TABLE VII

Recency of Training (of Those Having Done No Graduate Work in Chemistry)

Date of Bachelor's Degree	*No. of Teachers*	*Per Cent of All Teachers*
Last 10 years	20	47.6
20 years to 10 years ago	7	16.6
Over 20 years	1	2.38

Assuming that no undergraduate work has been done in chemistry since graduation, Table VII shows that nearly half of the teachers obtained bachelor's degrees during the last ten years, and that almost one-fifth received degrees more than ten years ago, and have done no further work in chemistry. In the light of the rapid progress being made in chemistry, it would appear very desirable for all teachers to continue their studies.

TABLE VIII

Teaching Time Devoted to Chemistry

Percentage of Time	*Number of Teachers*	*Per Cent*
20 and below	13	31
20–40	15	35.8
40–60	8	19
60–80	1	2.38
80–100	5	11.9

Table VIII shows that about one-third of the teachers devote 20% or less of their teaching time to chemistry, one-third devote 20–40% of their time, and one-third devote 40 to 100% of their time to chemistry teaching.

TABLE IX

Frequency of Other Subjects Taught by Teachers of Chemistry

Subjects Taught	*Number of Teachers*	*Per Cent*
Physics	22	52.4
Algebra	18	43
Geometry	15	35.7
Botany, Biology, Physiology	10	23.8
Agriculture	9	21.4
Physical Education	4	9.5
Civics, Sociology, Economics	3	7.15
Principal	3	7.15
General Science	3	7.15
Commercial Law, Business	2	4.75
Arithmetic	2	4.75
Manual Arts	2	4.75
Geology	1	2.38
Music	1	2.38

Table IX shows the frequency of other subjects taught by chemistry teachers; *i. e.*, physics is taught by over half of the chemistry teachers.

TABLE X

Data Regarding Teacher's Graduate and Related Work

		Per Cent
No. of teachers with Master's degrees	5	11.9
No. of teachers having done graduate work in chemistry	14	33.3
Range of graduate credit hours	2 to 75	
No. of teachers having had a course in methods of teaching chemistry	9	21.4
No. of teachers who have no credit in college mathematics	5	11.9
No. of teachers who have 15 or fewer credits in college mathematics	22	52.4
No. of teachers who have more than 15 credits in college mathematics	20	47.6
No. of teachers who have no credit in college physics	7	16.7
No. of teachers who have 15 or fewer credit hours in college physics	18	42.8
No. of teachers who have more than 15 credit hours in college physics	24	57.2

It appears that the training of some of the chemistry teachers in the related fields of physics and mathematics is inadequate.

TABLE XI

Age Distribution of Teachers

Age between:	*Number of Teachers*	*Per Cent*
20–25	4	9.5
26–30	9	21.4
31–35	11	26.2
36–40	11	26.2
41–50	7	16.7

Table XI shows that there are few very young teachers and no old teachers, and that about 75% are between 26 and 40 years of age.

TABLE XII

Professional Journals Read Regularly by Chemistry Teachers

Journals Read	*Number of Teachers*	*Per Cent*
JOURNAL OF CHEMICAL EDUCATION	28	66.7
Journal Amer. Chem. Society	10	23.8
School Science & Mathematics	9	21.4
Science	17	40.5

Table XII shows that the JOURNAL OF CHEMICAL EDUCATION is used by two-thirds of the teachers, and that the other three journals are used by one-fifth to two-fifths of the teachers.

Table XIII shows that the approximate cost per pupil of chemistry, aside from teacher's salary and the school plant, is nearly twice as large in schools with enrolments below 200 as in schools with enrolments between 200–500, and 2.6 times as much as in schools with over 500 students. The factor (0.06) represents the interest on the investment in equipment and

TABLE XIII

Approximate Annual Cost per Capita in Relation to Size of School (35 Schools)

Cost per Student Enrolled in Chemistry	*Size of School (Enrolment)* Below 200	200–500	Above 500
Below $2.50		4	4
$2.50 to $5.00	4	6	4
$5.00 to $7.50	6	2	1
$7.50 to $10.00			
Above $10.00	3	1	
Average cost by schools	8.23	4.44	3.14
Range of distribution	3.00 to 23.00	1.37 to 15.50	1.72 to 6.35

Approximate annual cost per pupil = [(0.06) (Value of equipment and supplies + annual expenditure + reference expenditure]/(no. enrolled).

[0.12 (value) + annual expenditure + reference expenditure]/(½ no. enrolled) = cost per pupil in schools giving chemistry in alternate years.

supplies carried over from year to year. This table represents no more than an approximation, since the data upon which it is based may be somewhat inaccurate.

TABLE XIV

Amounts Spent Annually for Reference Books and Journals for Student Use (41 Schools)

Amount	*Below 200* Schools	%	*200–500* Schools	%	*500 or over* Schools	%
0 to $5.00	12	28.6	6	14.3	4	9.5
$5.01 to $10	5	11.9	3	7.1	2	4.76
$10.01 to $20			3	7.1	3	7.1
$20.01 to $30			1	2.38	.	..
Over $30.00			1	2.38	1	2.38
Average per school	$4.18		$11.57		$12.20	
Range	$0–10.00		$0–50.00		$0–50.00	

Table XIV shows the distribution of schools with respect to the amounts reported as spent annually by the schools for reference books and journals for use by chemistry students.

LABORATORY ADMINISTRATION

Laboratory fees are charged by 20 schools or 47.6%.
Amount ranges between 50 cents and $3.00.
Breakage deposits are required by 22 schools or 51.4%.
Amount ranges between $1.00 and $2.00.

In answer to the question, "Do teacher demonstrations take the place entirely of student laboratory work?" forty-one schools answered "no" and one said, "mostly, because of inadequate facilities." All require student laboratory work, with this one exception, who answered "partly."

In 26 schools, 62% of the laboratory periods are single periods, mostly one hour. The other 16 or 38% have double periods.

In 18 schools (43%) project method of teaching is used and in 35 schools (83%) supervised study method is used. One wonders how supervised

study method can be used effectively with the small amount of reference material obtained yearly.

In 30 schools, (76%), supplies are administered in the laboratory by the teacher from a stock room; in only four of these cases was the teacher aided by an assistant.

It seems to the writer to be more desirable for the teacher to be present in the laboratory supervising the study and checking the work of the students, than to stay in the stock room to do the work which a high-school boy could do.

In six schools, an assistant administers the supplies from the stock room.

In two schools, the Freas system is used.

* * * *

The topics in the A. C. S. list of Minimum Essentials are included in the courses given in 33 schools, (79%), while six (14%), said that their courses did not include them. Three schools did not answer the question.

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Elementary qualitative analysis is included in the courses of 16 schools, (38%) and is not included in the courses of the other 26 (62%).

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Chemistry is taught as a 12th year subject in 13 schools, as an eleventh year subject in 9 schools, and a subject for mixed 11th and 12th year students in 20 schools.

Teachers' Problems

In answer to the question "What problems or difficulties confront you in your chemistry teaching?" the following were given by the number of teachers indicated.

Teachers' Suggestions	*No. of Times Given*
Insufficient time for covering subject matter	4
Students lack proper foundation	2
Inadequate laboratory	10
Lack of time for laboratory work	4
Lack of teacher time	5
To make course practical and still meet college requirements	5
Correlation of laboratory and class work	3
Lack of equipment and supplies	7
To understand experiments before performing them	2
Inadequate library	2
A satisfactory way of handling supplies	2
Valid method of measuring progress	1
Whether to replace student laboratory work by teacher demonstration	1
To handle dull students	2
To develop originality and initiative in students	1
Conflict with other classes during double laboratory periods	1

To get interest in problem work	1
Getting all students to get the scientific spirit	3
Getting individual work in laboratory	1

How Could a University Aid You in Your Work?

	No. of Times Given
1. Notify high-school teachers wherein students show lack of training	2
2. Suggest simple and effective set-ups for demonstrations	1
3. Emphasize the necessity for study of chemistry by the masses	2
4. By promoting science club for instructors—to call attention to modern theories and developments in chemistry	1
5. Assist in determining proper contents for a course	2
6. Give summer course in curriculum	2
7. Give summer course in new developments	2
8. Give course on up-to-date methods of teaching subject	6
9. Provide projection lantern slides, visual education materials	3
10. Provide good library reference materials	2
11. Help school boards to see necessity for more adequate equipment	1
12. By requiring courses in chemistry of all junior and senior high-school teachers	1
13. By furnishing a list of best reference books for high-school chemistry and keeping it revised	1
14. By giving popular competitive tests with appropriate rewards	1

Parents Make Bright Children Fail in School Work. In giving mental tests to children sent to the Bureau of Children's Guidance because of failure and difficult behavior in school, psychologists there made the interesting discovery that a large number of these backward children were "intellectually supernormal."

Dr. Jeanette Regensburg, a member of the staff of the Bureau, undertook a special study of these children in order to find out what would cause such very bright children to fail so conspicuously in the very type of work where they might be expected to shine. A report of her findings is soon to be published in *Archives of Psychology*.

The fault was found to lie often with the parents, and the chief hindrance to success was in a desire "to keep my baby a child as long as I can." A love for books and excessive reading did not lead to high grades in school for these bright children. In fact, the chances for school success were better with those who had been encouraged by the parents to give up books in favor of a more active chumming with "the gang."

"Granted superior intellectual endowment, school success is more fully assured if the child's experiences at home, while satisfying, nevertheless induce him to face weaning experiences from an early age in order to insure social independence, and if he is encouraged to be active, interested in the world outside him, and eager to make contact with the people in it," concludes Dr. Regensburg.

The grades of bright children most often began to fall off at the time they entered junior or senior high school. This, Dr. Regensburg believed, was because the school work and outside study is conducted in a more grown-up way in high school; there is less supervision and check-up. Because the bright child is often advanced until he is in a grade with others who are much older, he is often not mature enough to assume responsibility as well as the rest of his class.—*Science Service*

Abstracts

APPARATUS, LABORATORY PRACTICE, AND DEMONSTRATIONS

The Care of Platinum Laboratory Ware. D. JENNINGS. *Chem. Age*, **24**, 459 (May 23, 1931).—Platinum is attacked readily by aqua regia and to a certain extent by other chlorine-containing solutions. At red heat the caustic alkalies and some of the alkaline earth hydroxides attack it. It is corroded by sulfur, phosphorus, and arsenic and by easily reduced compounds of these elements. Brittleness is caused by peroxides, "per salts," silicon, and by carbon in the inner cone of the Bunsen flame. Platinum easily alloys with lead, tin, zinc, and antimony. Several methods of cleaning and repairing platinum ware are given. E. R. W.

Laboratory Furnaces for High-Temperature Work. N. R. DAVIS AND C. SYKES. *Chem. & Ind.*, **50**, 506–14 (June 19, 1931).—The construction and operation of a number of types of laboratory furnace are discussed in a well-illustrated article. E. R. W.

What Constitutes Laboratory Work. C. E. PRESTON. *High Sch. J.*, **14**, 269–72 (May, 1931).—After commenting upon some of the adverse criticisms which some college science instructors have made regarding the lecture-demonstration method of teaching high-school science laboratory work, the author raises the question as to what really constitutes laboratory work. He is of the opinion that such investigations as those by Professor Downing are much to be desired rather than severely criticized. The author says that in laboratory work it is the spirit rather than the form which counts. Laboratory study means working with things rather than with books about things. After all is said and done, the success of the laboratory method depends upon the teacher. C. M. P.

Can the Small High School Meet the Needs of a Modern Science Laboratory Equipment? O. E. BROWN. *Calif. Quart. Sec. Educ.*, **6**, 384–5 (June, 1931).—The ability of small high schools to meet the needs of modern science laboratory equipment depends upon the science courses to be offered, the method of teaching, the field or content covered, and the objectives or aims.

In schools of less than one hundred, only one laboratory room is necessary, even if the high school offers general science, biology, chemistry, and physics. This sequence is recommended. Only schools with an enrolment of over 500 need separate laboratories for each science. Modern science equipment is available to the small high school that plans wisely, budgets consistently, and reorganizes the science curriculum as necessity arises. C. M. P.

TEACHING OBJECTIVES, METHODS, AND SUGGESTIONS

Objectives of Education. T. W. GOSLING. *Educ. Method*, **10**, 519–24 (June, 1931).—Educational objectives change from age to age with the changing conditions of environment. Objectives which are now adequate may soon be found inadequate. The author discusses the four objectives found in the Sixth Yearbook of the Department of Superintendence, 1928, which are as follows:

1. To promote the development of an understanding and an adequate development of the self.
2. To promote the development of an understanding and an appreciation of the world of nature.
3. To promote the development of an understanding and an appreciation of organized society.
4. To promote the development of an appreciation of the force of law and of love that is operating universally.

In the opinion of the author these objectives of education comprehend the entire range of human life and of human relationships. C. M. P.

ADMINISTRATIVE PROBLEMS AND DEVICES; CURRICULA

Physical Methods and Measurements. P. E. KLOPSTEG. *Can. Chem. & Met.*, **15**, 130–3 (May, 1931).—Chemists in part use physical methods of measurement, but as a whole the chemist knows too little of physical instruments. The introductory courses of chemistry have the tendency to give the student the impression that chemistry is a descriptive science. As the student advances an introduction is made to the

use of the analytical balance, burets, pipets, and volumetric flasks. Upon the whole the student has not acquired a fundamental knowledge of scientific measurements. It is thought that more knowledge of physics than is furnished by an introductory course would better fit the student with a knowledge of scientific measurements, but at present the chemistry curriculum is already so filled that considerable difficulty is encountered in planning the student's course. A course especially designed for the chemistry student should be offered. The course is outlined to give attention to theory of measurements, and to stress probable errors in such measurements. It should be designed to bring out with the greatest possible clarity the distinction between accuracy and precision. After the student has completed the elementary courses in physics and prerequisite mathematics, a course of typical measurements should be adopted which would include mechanics, sound, heat, light, magnetism, electricity, properties of matter, and atomic physics. These measurements should be preceded by a discussion of the principles involved, of the possible sources of errors, and means of avoiding or eliminating errors. There are probably no such physics courses offered in the American university today, but this is due to the fact that the chemists have not as yet demanded such a course in their curriculum. R. L. H.

The Place of the University in the Solution of Technical Problems. J. W. COBB. *Chem. & Ind.*, **50,** 548–50 (July 3, 1931).—The solution of a major technical problem confronting an industry may involve three stages: laboratory investigation, experimental working on a small works scale, trial on full works scale. The first of these may be well carried out in the university laboratory, but few laboratories are prepared to handle the second stage, while the third must of necessity be carried out in a plant.

The real function of the university should be to so train men that they may successfully solve industrial problems. In so far as laboratory investigation of technical problems aids in this training it has a place in university laboratories. E. R. W.

KEEPING UP WITH CHEMISTRY

Water Treatment and Purification. J. B. HUTTL. *Eng. & Mining J.*, **131,** 513–4 (June 8, 1931).—A discussion of the methods used for the purification of water for boiler purposes. The more economical and more general methods are filtration for water carrying much suspended matter, and lime-soda treatment for removal of hardness due largely to bicarbonates. The nature and some of the advantages of the permutite process are also discussed. A discussion of the condition under which each is most advantageously used is also given. G. W. S.

The Helium Industry. H. M. LANGTON. *Chem. & Ind.*, **50,** 472–3 (June 5, 1931).—Helium was named by Lockyer in 1868, after his discovery of the then unknown element in the sun by spectroscopic investigation. Prior to 1917 helium was little more than a laboratory curiosity, yet during the year ending June 30, 1930, nearly ten million cubic feet of the gas was separated from natural gas. Most of the known sources of the gas are in the United States. Methods by which helium is separated from natural gas, and uses of the element, are discussed briefly. E. R. W.

Mars—The Chemical Industrialist. W. HAYNES. *Chem. Markets*, **28,** 148–52 (Feb., 1931).—The three thousand items of modern commerce were all influenced by the World War. The war showed that modern battles are won as much by the farmer and factory hand as by the soldier at the front. The war brought with it not only new chemicals but also new processes. When previous to this time the world depended almost entirely upon natural sources for its nitrate supply, there came a demand through blockades for a synthetic production of nitrates. This was accomplished successfully by the development of the Haber process of nitrogen fixation, which is the direct union of nitrogen and hydrogen at 900°C. and 3000 lb. pressure and by the aid of a catalyst. Since the close of the World War it was necessary to extend the consumption of nitrates and ammonia. This was done by making fertilizer concentrates from ammonia and nitric acid, and by extending the use of ammonia as a refrigerant. R. L. H.

Possible Utilization of Natural Gas for the Production of Chemical Products. H. M. SMITH. *Gas Service J.*, **5,** 10–3 (April, 1931).—A large quantity of natural gas has resulted from the production of oil in the development of new oil wells. There is a considerable excess above that which is consumed, and hitherto this surplus has been wasted by being blown into the air. Researches are now being conducted to utilize the surplus gas in the manufacture of chemical products. There are three general methods which make this possible. These methods are: (1) Controlled oxidation, by steam or oxygen; (2) Pyrolysis, the breaking of the hydrocarbon molecule into its parts and the reuniting of these parts into a new chemical compound; (3) Chlori-

nation, which replaces one or more of the hydrogens of the hydrocarbon molecule with chlorine. By partial oxidization fairly pure hydrogen is obtained which may be used for hydrogenation processes. At 900°C. methane reacts with steam to form a mixture of hydrogen and carbon monoxide, which may be reunited by the aid of suitable catalysts, temperature, and pressure to form methanol. By pyrolysis, hydrogen, acetylene, butadiene, ethylene, propylene, and butylene may be formed. By chlorination the following products may be formed: methylene chloride, chloroform, carbon tetrachloride, and methyl chloride. R. L. H.

Potash, Can the United States Free Itself from Foreign Dependence? G. W. STOCKING. *Chem. Markets*, **28**, 368–72 (April, 1931).—The presence of 5.4% potassium chloride, in a well at Dickens County, Texas, caused a wide search to be made for deposits of potash. After considerable drilling was done several wells were found which contained potash. These wells were found in Texas and New Mexico, and were found to contain polyhalite and sylvite. The beds of the deposits were found at depths ranging from 750 to 2200 feet, from two to seven feet thick and contained from 10 to 20% potassium oxide. These findings show the American potash deposits compare favorably with those of Germany. R. L. H.

Solid CO_2 Technology Defers to Distribution Problems. G. T. REICH. *Chem. & Met. Eng.*, **38**, 270–4 (May, 1931).—Solid carbon dioxide has been known since 1834 when it was prepared by Thilorier, but was not used commercially until 1925. Solid carbon dioxide has many advantages over water ice, such as cleanliness, low temperature range, compactness, better insulation (by the gaseous carbon dioxide). With all the advantages which solid carbon dioxide has over water ice the cost of the production of solid carbon dioxide prevents it from being used as widely as water ice. Solid is made in the simplest form by expanding liquid carbon dioxide into a canvas bag. By the use of this method there is a 20–25% conversion into the solid form. The actual cost of production of solid carbon dioxide at Niagara Falls, N. Y., is estimated at $1.00 per ton as estimated from the power costs. Solid carbon dioxide as a refrigerant in railway cars has been used with good results. Whether this method will be adopted depends upon cost of cars which are adapted to the use of the new refrigerant and railroad policies. At present most of the solid carbon dioxide is being used in the ice-cream industries. R. L. H.

Nickel-Clad Tank Cars for Caustic Soda. L. A. BELDING. *Inco*, **10**, No. 4 (1931). (*Cf. Chem. Met. Eng.* for Feb., 1931).—The physical constants of nickel and steel are such as to make these two substances well suited to the production of rolled plates. Slabs of nickel and steel, with carefully prepared surfaces, are placed in intimate contact, and the two heated in the proper atmosphere and rolled to the finished plate. Bonding results because the two form solid solutions at the plane of contact. The stiffening of requirements of the rayon and soap industries for caustic soda of low iron content, and the fact that production costs of solid caustic soda are greater than for liquid solutions has caused a search for a material of which a tank car could be made and which would not introduce impurities into the soda. Tank cars constructed of nickel-clad steel having an all-nickel inner surface fulfil the requirements. H. T. B.

Alloys at Work. ANON. *Inco*, **10**, No. 4 (1931).—"In serving the complicated needs of a highly geared civilization, further development becomes as much a search for better materials of construction as for improved mechanisms—materials that will stand up under the stress of present-day conditions. . . . Of prime importance in the search for materials is the success of the modern metallurgical laboratory in producing alloys to meet varying conditions. Of the many alloys now in use, those containing nickel are among the most numerous and important." Nickel imparts strength, resistance to wear and corrosion, and toughness. In a test in which an automobile motor was driven through a dynamometer under conditions equivalent to a speed of 18 miles per hour in second gear up an 18% grade, gears made of case-hardened nickel steel were in good condition at the end of 166 hours running, while gears of other steel alloys had failed at the end of 25 hours. H. T. B.

Magnesium Compounds in the United States. P. M. TYLER. *Chem. Age*, **24**, 555–6 (June 20, 1931).—Precipitated magnesium carbonate, a basic carbonate, is used in the manufacture of boiler coverings and molded insulations. From 50,000 to 75,000 tons are used annually. Purified magnesium sulfate is used in the drug industry, while the crude product is for sizing textiles, weighting silks, paper and leather, and in the manufacture of rayon by the Viscose process. Crude magnesium oxide is used in compounding rubber and in insulation materials. Magnesium chloride is used as the raw material in the manufacture of metallic magnesium, it is also used in preparation of

jointless flooring, stucco, and artificial wood. Other magnesium compounds, used in much smaller amounts, are mentioned. E. R. W.

Visualizing the Vitamin. S. RANDOLPH. *Hygeia*, **9**, 544–5 (June, 1931).—Many housewives plan their meals about a protein and fat menu, *i. e.*, they select the meat first, a method which is apt to sacrifice vitamins. If meals are planned with vitamins first in mind there is little danger of providing too little protein. Vitamin A, without which blindness may follow, is present in butter, eggs, meat, and leafy vegetables. Vitamin B is not readily destroyed by ordinary cooking and is present in spinach, turnip tops, radishes, water cress, lettuce; raw cabbage, and brussels sprouts. Vitamin C, which prevents scurvy, is destroyed by cooking. It may be found in tomatoes, orange juice, fresh vegetables such as celery and fresh peas, and unpasteurized milk. Vitamin D is conveniently secured in cod-liver oil. Calcium for bodily needs may be obtained in milk. The adult should not feel that milk is a food for children only. H. T. B.

Recent Advances in the Chemistry of Vitamins. See this title, near bottom of this page.

Modern Developments in Printing. L. WILD. *Chem. & Ind.*, **50**, 530–2 (June 26, 1931).—Lithography, used extensively for multi-color illustration work, consists briefly, in preparing a design with oleic acid on a surface of zinc, aluminum, or stone; the portions of the figure not to be colored are covered with a solution containing gum arabic and salts of arabic acid. The ink, the vehicle of which is linseed oil, wets and colors the oleic acid design but is repelled by the gum arabic coating.

Intaglio printing and the composition of inks are discussed briefly. E. R. W.

The Pathology of Some Industrial Poisons. A. J. AMOR. *Chem. & Ind.*, **50**, 475–6 (June 5, 1931).—The affinity of hemoglobin for carbon monoxide is about three hundred times greater than its affinity for oxygen. If air contains 14% oxygen and 0.047% carbon monoxide the hemoglobin shares itself equally between the two gases. The carboxyhemoglobin formed from hemoglobin and carbon monoxide does not carry oxygen and it inhibits the circulation of oxyhemoglobin. The action of carbon monoxide then causes anoxemia or "oxygen lack."

Arsine is from ten to twenty times more dangerous than carbon monoxide, only 0.3 g. being a fatal dose to the average man. This gas passes through the cell walls unchanged, and ruptures the lipoid envelope of the red blood corpuscles. A sudden over-production of bile colors the tissues yellow, "a jaundice condition," an important sign of arsine poisoning.

There are three classical kinds of lead poisoning, colic, paralysis, and encephalopathy. The number of blood corpuscles and the amount of hemoglobin may be lowered and anemia results. Degeneration of the motor nerves supplying the muscles of the forearms and hands causes paralysis of these members. E. R. W.

What Fur? I. GRIFFITH. *Am. J. Pharm.*, **103**, 353–88 (July, 1931).—A Popular Science Lecture delivered at the Phila. Coll. of Pharm. & Sci.

By "Burbanking" foxes the expensive silver fox is now turned out on a quantity basis. By selective breeding the lowly bunny takes on a new significance, for experts can turn them out in any color. Through the ingenuity of modern industry and the color chemist we no longer need to concern ourselves about the availability of even the most expensive furs. If the leopard cannot change his spots, the chemist can. Chemically, fur is a protein substance. The chemical nature of fur must be borne in mind during the cleaning, dyeing, and preserving of furs. In the hat industry practical use is made of the fact that fur combines with mercury, nitric acid, barium, organic and inorganic peroxides, such linkage increasing the felting property of felt. The so-called derby hat is strangely made of amber shellac and fur, about half and half. "Making a purse out of a sow's ear" can be considered a typographical error, for if we change the word to cow, the proverb becomes a truism. The fur lining of a cow's ear sells for $10 a pound and is used in coach painter's brushes. The article is accompanied by a bibliography of fur facts, fur trade, and fur animals. G. O.

SCIENTIFIC REVIEWS AND BIBLIOGRAPHIES

Recent Advances in the Chemistry of the Vitamins. *Nature*, **128**, 39–40 (July 4, 1931).—At a meeting of the Royal Society held on June 18, the President, Sir Frederick Gowland Hopkins, opened a discussion on the chemistry of the vitamins, which was confined to the Vitamins D, A, and B complex. F. B. D.

Helium and Its Properties. E. RUTHERFORD. *Nature*, **128**, 137–8 (July 25, 1931).—An abstract of the Friday evening discourse delivered at the Royal Institution on March 27, 1931. F. B. D.

HISTORICAL AND BIOGRAPHICAL

Concerning the Frontispiece, *Cf.:* "The Follies of Science in the Court of Rudolph II," HENRY CARRINGTON BOLTON, Pharmaceutical Review Publishing Co., Milwaukee, Wis., **1904.**

Teyler's Museum in Haarlem. E. COHEN. *Chem. Weekblad,* **28,** 403–8 (July 4, (1931) (In Dutch).—Pieter Teyler van der Hulst, 1702–78, a rich merchant in Haarlem, left his fortune for the maintenance of a museum in physical sciences and natural history, providing also for curators and lecturers upon the foundation, which exists at the present time. The first director of the collections was Martinus Van Marum (1750-1837). He was one of the first adherents of the new theories of Lavoisier, and helped introduce the new ideas into Holland.

John Griscom, who visited the museum in 1819, speaks of meeting Van Marum, and describes at that time his impressions of the collections.

Dr. Cohen quotes an account of the visit of Napoleon to the museum in 1831 and gives an account of the history of the institution and its efforts to popularize knowledge.

The article is illustrated with reproductions of old engravings of Teyler, Van Marum, and of the Museum. F. B. D.

Ampère House to Be Preserved. See this title, page 2093.

The Gastric Juice. "A Classic of Science." W. BEAUMONT. *Sci. News Letter,* **20,** 10–1 (July 4, 1931).—A trapper, recovered from a shotgun wound which pierced his stomach, acted as a laboratory for the tests which are recorded in his paper.

Chemical analysis at the hands of Professors Dunglison and Emmett showed that gastric juice contains free muriatic acid, acetic acid, phosphates with bases of potash, soda, magnesia, and lime. The muriatic acid was found to be present in astonishing amounts.

Gastric juice is said to be "the most general solvent in nature—even the hardest bone cannot withstand its action." The author further states that considered from all angles he cannot but conclude "that the change effected by it on all aliment is purely chemical. We must regard this fluid as a chemical agent and its operation a chemical action."

Some properties exhibited by it are enumerated as: a clear transparent fluid, inodorous, a little saltish and very perceptibly acid, readily diffusible in water, coagulates albumin, and powerfully antiseptic.

The author found, contrary to popular belief, that the food did not go to the stomach and remain there for a time before digestion was started but that digestion occurred as the food passed through. "The gastric juice is ready to commence its work of solution soon after the first mouthful is swallowed." B. C. H.

The Beginnings of Science. C. SINGER. *Nature,* **128,** 7–10 (July 4, 1931).—This is the inaugural address delivered to the Second International Congress of the History of Science and Technology on June 29. The author states that the history of science is evolutionary in character, showing a general development of achievement. On the other hand the only written works that have come down to us from the remote past in science are from Greek and Egyptian sources and have to do with medicine and with mathematics. Possibly the oldest document of this kind is the Moscow Papyrus (from the Middle Kingdom), the translation of which was published in full only a few months ago. It contains the determination of the volume of a truncated pyramid and the area of a hemisphere. Both are correct, the latter on the basis of the Egyptian value for π as 3.16. F. B. D.

Standards of Measurement: Their History and Development. *Nature,* **128,** 17–28 (July 4, 1931).—By Sir Richard Glazebrook, from the Guthrie Lecture for 1931, delivered before the Physical Society of London on May 15. This is an extremely interesting résumé of the sources of our standard units of length and weight, including time and electrical standards. F. B. D.

Chloroform Reaches 100th Anniversary. ANON. *Hygeia,* **9,** 534 (June, 1931).—Chloroform was discovered during 1831 by three different scientists working independently. Dr. Samuel Guthrie was the American discoverer and obtained the substance while working with chloride of lime and alcohol. It was first used as an anesthetic in 1847. The discovery of chloroform has been suggested as an event to be commemorated at the Century of Progress in Chicago in 1933. H. T. B.

Pioneer Drug Milling in the U. S. J. W. ENGLAND. *Am. J. Pharm.,* **103,** 389–98 (July, 1931).—The pioneer drug mill in this country and perhaps in the world was established in 1812 at Philadelphia by Chas. V. Hagner. Various forms of milling machines are illustrated, and some of the older millers of the U. S. are listed. The substitution of machinery for mortar and pestle first brought much displeasure and

amazement, for how could ipecac and cream of tartar ground over night be as good and fine as that produced by hand over a period of months? G. O.

EDUCATIONAL MEASUREMENTS AND DATA

Four Types of Examination Compared and Evaluated. A. C. EURICH. *J. Educ. Psychol.*, **22**, 268–78 (Apr., 1931).—This is the résumé of a study conducted at the University of Minnesota. The study involving two experimental groups included 205 students enrolled in statistical methods and in educational psychology. Four different kinds of tests covering exactly the same subject matter were used: essay, completion, multiple-choice and true-false. One type of test was found to be as reliable as another in so far as the intercorrelations reveal. Also all tests seem to have about equal validity. The essay type had a lower correlation with intelligence scores. Students preferred the true-false and the multiple-choice type of tests. C. M. P.

Research Scholarships and Fellowships Supported by Industry. C. J. WEST AND C. HULL. *Ind. Eng. Chem., News Ed.*, **9**, 209–12 (July 10, 1931).—This list was compiled from data supplied by the organizations supporting the scholarships and fellowships. G. W. S.

THE PHILOSOPHY OF SCIENCE

Modern Theories of the Universe. J. JEANS. *Sci. Mo.*, **33**, 12–6 (July, 1931).—A word picture of the changes in our concept of the universe during the past fifty years. During the mid-Victorian age, science did not contemplate the universe at all. J. compares science at that time to a series of roads diverging from ourselves in different directions—physics in one direction, chemistry in another, etc. Mankind was taken as the center from which science worked. The particles of which matter was built were too small for examination in those days. The inevitable result was that the universe was thought of as being something like the material tool with which it was examined, *i. e.*, bodies were thought of as moving only as they were being pushed or pulled. Discoveries during the years 1896–1905 gave science a new interest in which the scientist first began to contemplate the universe as a whole, and instead of the diverging roads he began to think of it as a lot of roads converging on a central point, leading to an understanding of the universe as a whole. A few of these discoveries were the electron, radio-activity, and the quantum and relativity theories. Now science surveys the universe from the largest objects known in it, the spiral nebulae, to the smallest objects, the electrons and protons. The universe can no longer be interpreted in terms of a mechanical phenomenon but must be explained from a mathematical standpoint. In these terms only is it possible to explain the finiteness of time and space. G. W. S.

PROFESSIONAL

Ethics of the Teaching Profession. *Research Bull., Nat. Educ. Assn.*, **9**, 1–89 (Jan., 1931).—This is a bulletin which every member of the teaching profession should read and possess. Part I discusses instruction in professional ethics: current practices in the schools of eight professions and what arrangements for instruction in professional ethics should schools for teachers provide? An analysis of practices in the following professions is included: Architecture; Dentistry; Nursing; Journalism; Business and Commerce; Law; Medicine; Teaching.

Part II discusses standards of professional conduct among teachers as to: (1) Selection and organization of material; (2) General principles of conduct; (3) Relation with pupils, parents, and community; (4) Relations with associates; (5) Relation to the profession; (6) Securing and terminating employment; (7) Conduct in connection with teachers' agencies, publishing and school supply houses. A selected bibliography and also the code of ethics of the National Education Association are included. C. M. P.

Salaries in City School Systems. *1930–31 Research Bull., Nat. Educ. Assn.*, **9**, 163–226 (May, 1931).—A list of 1632 cities having 2500 or over in population is the basis of this report. Fifty-one tables and seven charts are included. Statistics showing the minimum, median, and maximum salaries paid elementary teachers, elementary principals, junior high-school teachers, junior high-school principals, high-school teachers, high-school principals, and city superintendents are included. C. M. P.

CONTEMPORARY NEWS AND COMMENTS IN CHEMISTRY AND EDUCATION

Engineering and Science. I. A. PALMER. *J. Eng. Educ.*, **21**, 609–15 (May, 1931).—The scientist is knowledge-hungry, he derives pleasure from learning more about the unknown, and is not concerned about the monetary and practical value of

the results of his researches. His social contacts are purely secondary. The engineer must be practical, he should be able to obtain and use material he needs from a number of fields. He must know something of business, and must be able to maintain personal relations with others. It has been said that "the scientist knows a great deal about one subject whereas the engineer should be moderately familiar with a number of subjects." Scientific facts may be known for some time before they are put to practical use. The scientist and engineer are in a sense complementary. "The primary purpose of a technical school is not to turn out scientists, scholars, research men, teachers, mechanics, or business men, but engineers." The careers of students should be molded with this thought constantly in mind. H. T. B.

Ampère House to Be Preserved. *Nature*, **128,** 111 (July 18, 1931).—Thanks to the generosity of S. and H. Behn, the house in which A. M. Ampère, the great French physicist, spent his boyhood and youth, has been presented to the French Society of Electricians. The house is situated at Polemieux-les-Mont-d'Or. A plaque has been affixed on the entrance of the house commemorating the name of Ampère, and an account of the ceremonies that occurred when the Society took possession of the house has been published.

Ampère was born in 1775. In 1793 when he was a lad of eighteen his father was executed on the scaffold—a victim of the Revolution. Ampère, while mainly a physicist, is known to chemists for his independent work which corroborated Avogadro's Hypothesis. He died at Marseilles in 1836, but later his remains were transferred to the Montmartre Cemetery. F. B. D.

The International Congress of the History of Science and Technology. T. GREENWOOD. *Nature*, **128,** 77–9 (July 11, 1931).—The Second International Congress of the History of Science and Technology held a very successful series of meetings in London, June 29–July 4.

The work of the Congress was divided in four main sections which dealt with the following general topics: 1—The Sciences as an Integral Part of General Historical Study, 2—The Teaching of the History of Science, 3—Historical and Contemporary Inter-relationship of the Physical and Biological Sciences, 4—The Interdependence of Pure and Applied Science.

"The achievements of the meeting showed that the history of science can take its place not only among the departments of high scholarship, but also as an integral part of training and discipline in the general study of history. Science cannot assume her just position in education until the educator himself recognizes the part that science has taken in shaping the social and intellectual environment in which we live. If the scientific process comes to be recognized as a great part of our great inheritance, the Congress will have gone a good way toward achieving its objective." F. B. D.

Chemistry Building for Miami University. See page 2095.
First Award of A. C. Langmuir Prize to Pauling. See page 2096.
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Careful Cooking Best Preventive for Food Poisoning. See page 2098.
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Pellagra May Be Due to Lack of Iron in Diet. See page 2099.
Plant Yields Substance 300 Times as Sweet as Sugar. See page 2097.

GENERAL

Technology and Material Progress. W. R. WHITNEY. *Gen. Elec. Rev.*, **34,** 403–5 (July, 1931).—"The only fixed law in the universe is that there shall be perpetual change in all things. We are living in a dynamic, not a static universe. . . . Man is essentially spiritual, but his tokens of values, his media of exchange, the flowers of goodwill to others call for material devices. . . . If there is one thing modern mechanical civilization can do, it is to free people from slavery, and strew spiritual opportunity along their paths. . . . There are errors in scientific conclusions now, just as there have been in the past. Hardly a single scientific fact of one century remains adequate for the next." Society is in a state of improvement. Everywhere there is change, with people seeking something better. H. T. B.

The Ciné Scientist. E. W. PAGE AND W. A. PALMER. *Movie Makers*, **5,** 768 (Dec., 1930).—The best results to be obtained from educational pictures are to have a production of facts accompanied by entertainment. The field for educational films is unlimited. There are many branches in the field of zoölogy for filming the action

and habits of animals. Likewise the motion picture is applicable to botany, medicine, and physics. R. L. H.

Commercial Research. L. A. WATT. *Chem. & Met. Eng.*, **38**, 8–9 (Jan., 1931).—Commercial research provides a way for making the most of what is at hand as well as *guiding the way for expansion.* Some of the evaluated factors are: (1) process to be used; (2) raw materials; (3) plant expansion; (4) cost of production; (5) competition; (6) demand for the product; (7) patent situation. R. L. H.

Alchemy in Old New England. *Three hundred years ago the John Winthrops, father and son, came to Boston. The elder John Winthrop became the second governor of the Massachusetts Bay Colony, and the younger in due course became the first governor of Connecticut. . . .They also gave economic life to New England, especially the younger Winthrop who was alchemist, chemist, physician, and the first manufacturing chemist and practical technologist in the English colonies of North America.*

John Winthrop, Jr., imported chemicals and laboratory apparatus from England in 1633. In 1643 he began the manufacture of iron at Lynn and Braintree and, in 1648, he was granted a commission by the General Court of Massachusetts to manufacture salt. Two years later he planned a chemical stock company, the first in America, for the manufacture of saltpeter, and in the year afterward was granted by Connecticut the first monopoly for the working of lead, copper, tin, antimony, vitriol, alum, and other materials. He also started the manufacture of glass. In 1662, during a trip to England, he read before the Royal Society a paper on the manufacture of tar in New England and in the following year carried out for the Royal Society experiments on the brewing of beer from maize. He was a famous practitioner of medicine, and made use of chemical remedies which he prepared himself.

He was a member of the Royal Society, and a friend and correspondent of Robert Boyle, Kenelm Digby, and other men of science in England. In his large library there were many books devoted to chemistry and medicine, and also a number of alchemical books which had formerly belonged to Dr. John Dee, the physician of Queen Elizabeth. Many of his books, manuscripts, and letters are preserved at Boston today in the library of the Massachusetts Historical Society. He died at Boston, and is buried in the same tomb with his father in the churchyard of King's Chapel.

Winthrop's friend, George Stirk or Starkey, was the most famous of American alchemists. The son of a Bermuda clergyman, he came to Harvard for his education and graduated in 1646. He practiced medicine in Cambridge or Boston in 1647, and was established in Boston in 1648–1650. Later he went to England. His pills and his oil of sulfur were well-known nostrums, and his alchemical writings, issued in part under his own name and in part under the pseudonym of Eirenaeus Philalethes, were long held in high repute by the adepts. He claimed to have discovered the secret of transmutation in 1645, and actually convinced a number of reputable persons that he had done so. He died of the plague at London in 1665, according to one account, while in prison for his debts, according to another, because he dissected the body of a plague victim.

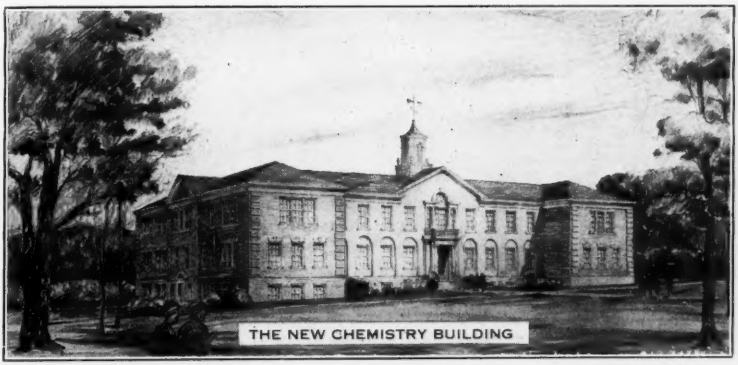
Interest in alchemy was prevalent in the New England colonies. In 1657 Jonathan Brewster, the son of Elder Brewster of Plymouth Colony, was carrying on the search for the Grand Arcanum in a cabin at the trading post of Manheken (Monhegan), afterward a part of Norwich, Conn. He wrote to John Winthrop, Jr., telling of his experiments in the preparation of the red and white elixirs and of his doubts of their successful outcome. William Avery was seeking for the alkahest at Boston in 1684 and had taught his son, Jonathan, to be "an assiduous laborer at the chemical fire," as is attested by his letters to Robert Boyle. Other later alchemists were Judge Danforth, Dr. Aeneas Munson, and President Ezra Stiles of Yale, the last-named being contemporary with the American Revolution.—*The Technology Review*

Contemporary News in Chemistry and Education

CHEMISTRY BUILDING FOR MIAMI UNIVERSITY

Miami honored one of her most distinguished living alumni when the board of trustees with the recommendation of the president of the university voted to name the newly finished chemistry building Hughes Hall. This is named for R. M. HUGHES, Miami 1893, professor of chemistry 1898 to 1913 and president of Miami University 1913 to 1927. In 1927 he became president of Iowa State College.

The picture of the building shows it as it will be when completed. The central



THE NEW CHEMISTRY BUILDING

portion, which is finished, contains the offices for the staff, the class and lecture rooms, the storage and dispensing rooms, and the laboratories for advanced work. The wings will contain the laboratories for the regular chemistry courses and will be erected as soon as money is available from the state.

This section is fireproof throughout and embodies many of the features included in modern chemistry buildings.

The alumni, friends, and faculty of Miami University are pleased to commemorate so distinguished a name as Hughes by so handsome a building. They believe that it is a fitting testimonial of their appreciation of R. M. Hughes as an alumnus, loyal friend, chemist, teacher of chemistry, and administrator.

NEW YORK CANCER COMMITTEE APPEALS FOR AID

In these days of general business depression, when the immediate need must be met, we have a tendency, unhappily, in responding to the emergency, to overlook other less spectacular but absolutely essential charities. Yet the sufferings of hard times are many fold increased when serious or fatal illness occurs. Too often the family is broken up as the result of illness which might have been avoided; and the situation is then indeed tragic.

With insufficient funds the agencies in the field of health education are trying to meet present conditions, to respond to demands even heavier than in normal times, and to carry on so that the ground already won shall not be lost. The New York City Cancer Committee of the American Society for the Control of Cancer, one of these agencies, supported entirely by public subscription, calls attention to the increased need for cancer education during the depression, when so many who lack funds are apt to neglect

their health, disregarding warning signs, and trust to luck. Particularly in the case of cancer is delay dangerous and early examination and treatment imperatively necessary, since in early treatment lies the only hope of escape. It is gratifying to be assured that as a result of public education in cancer during the past few years, patients suffering from the disease are coming to physicians at earlier stages in its development, when there is chance of cure. This is due largely to the work of the Society, and is a most helpful advance.

The financing of such work is always a task, and in times of depression a much more difficult one. To secure funds necessary for carrying on its campaign throughout the year, and for responding to the resulting appeals for help, for advice in the particular case, and for information in general, the New York City Cancer Committee of the American Society for the Control of Cancer has put out an address label which carries the emblem of its work—a sword twined with the healing symbol, typifying the fight for humanity against disease. The use of these strikingly effective labels, an ornament to the Christmas package, indicates endorsement of the work and participation in it. They are sold in lots of ten for one dollar, all the proceeds going to the Committee.

Those who are in touch with the situation tell us that the need is great, and no one who has seen anything of the ravages of cancer in its later stages can doubt that this is so. The work of cancer education must go on, and the response to the appeal for funds to continue it should be generous.

Labels can be ordered by mail, in any quantity, from the New York City Cancer Committee, 34 East 75th Street, New York.

FIRST AWARD OF A. C. LANGMUIR PRIZE TO PAULING

On September 2nd, at the meeting of the American Chemical Society in Buffalo, N. Y., DR. LINUS C. PAULING, of the California Institute of Technology, received the first award by the American Chemical Society of the $1000 A. C. Langmuir prize,* granted for the "most outstanding research in pure chemistry conducted by a scientist who is on the threshold of his career and not over 30 years of age." Dr. Pauling's research has been in the field of quantum mechanics and the nature of chemical bonds. He has published approximately fifty papers on original research.

Wide World Photos

The recipient of the Langmuir award is just 30 years old. He was born in Portland, Oregon, and educated at the Oregon Agricultural College and the California Institute of Technology, having received his doctor's degree from the latter institution in 1925.

EXPERT TO STUDY EDUCATION BY RADIO

Appointment of CLINE M. KOON, assistant director of the Ohio School of the Air for the past two years, to fill the newly created post in the Office of Education, Specialist in Education by Radio, has been announced by the Secretary of the Interior

* J. CHEM. EDUC., **8**, 993 (May, 1931).

Duties of the new Office of Education specialist will be to initiate and conduct research studies of radio as an educational agency; to organize and maintain an informational and advisory service to schools and other agencies interested in the field of education by radio; to become familiar with college and university extension work so that the part radio as a tool may take in this field may be evaluated; and to prepare material for publication on phases of education by radio.

Mr. Koon was graduated from West Virginia University in 1915 with the degree of Bachelor of Science, and received his A.M. degree from Teachers' College, Columbia University, three years later. For nine years he was principal of high schools in West Virginia.

Creation of the radio specialist position in the Office of Education recognizes the growing importance of education by radio. It was authorized as a result of many recommendations, including one of the National Advisory Committee on Education by radio last year, which stressed the need of such a section in the Office of Education.

The newly appointed radio specialist, through his affiliation with the successful Ohio School of the Air, has made many contacts in the radio field which will be valuable to him in conducting this phase of educational activity in the Federal Office of Education. He assisted in directing educational broadcasts which are now heard regularly in approximately 8000 schoolrooms.

PROFESSOR LAWALL APPOINTED TO LEAGUE OF NATIONS COMMITTEE

PROFESSOR CHARLES H. LAWALL, Dean of the Philadelphia College of Pharmacy and Science and Secretary of the Committee of Revision of the United States Pharmacopeia, has just been notified by the Medical Director of the Health Committee of the League of Nations of his appointment to represent the United States of America on the International Committee for Assaying Opium.

The chairman of this committee is DR. L. VAN ITALLIE, professor of pharmacy and toxicology at the University of Leyden. Other members of the committee are pharmaceutical chemists from Denmark, Switzerland, France, Austria, Germany, Japan, and Great Britain, one member from each country.

The purpose of the committee is to make a systematic study of the more important methods of opium assay, with a view to the approval of some one method for official adoption by the various pharmacopeias of the world. The appointment of this committee was made at the request of the Advisory Committee on Traffic in Opium and Other Dangerous Drugs, which has been in session at Geneva since May of this year.

PLANT YIELDS SUBSTANCE 300 TIMES AS SWEET AS SUGAR

A natural substance three hundred times sweeter than cane sugar, rivaling some of the coal-tar products of chemical laboratories, has been shown by two French chemists to consist of a chemical union of common glucose and another compound which has little or no taste. United, they are intensely sweet; divided, they are not even as sweet as ordinary sugar.

The compound bears the chemical name "stevioside," because it occurs in a South American plant known to botanists as Stevia. The plant itself was first introduced to the scientific world about the beginning of the present century; it is a close relative of such familiar North American weeds as boneset, Joe-Pye-weed, and the plant that causes occasional outbreaks of milk sickness in the Midwest. After its discovery by Europeans it rapidly acquired the name of "the sweetest plant in the world." A very small piece sufficed to sweeten a cup of coffee or tea.

During the past generation several partially successful attempts have been made to isolate and study the particular substance in the plant that made it so intensely sweet. It has remained, however, for the French chemists, MM. BRIDDEL and

LAVIELLE, to accomplish the final purification. They have discovered, to their surprise, that the sweet crystals of stevioside, upon chemical treatment to remove a part of the combined water in them, break apart into about 60 per cent common glucose and 40 per cent of a new stuff which they called "steviol." The latter has no taste, but combined with the glucose it produces a most poignantly sweet substance.

Mm. Briddel and Lavielle made another interesting discovery, the significance of which is not yet clear. If they freeze a 50 per cent solution of the intensely sweet stevioside they obtain a mat of fine needle crystals, which contain more chemically combined water than the original substance, and which are only faintly sweet. The sweetness of stevioside seems to depend on the presence of an exact amount of water in combination with the glucose and steviol; a trifle more or a trifle less spoils the effect.—*Science Service*

CAREFUL COOKING BEST PREVENTIVE FOR FOOD POISONING

Food poisoning may be caused by a great variety of factors but outbreaks can more frequently be traced to carelessness in the kitchen than to the use of unfit ingredients.

Thorough heating of all food products; protection against contamination by dust, flies or other insects, rats and mice, and against contamination by human carriers of disease-producing bacteria; cleanliness and careful refrigeration are among the recommended precautions.

Botulism, an increasingly serious source of food poisoning, is caused most frequently by home-canned goods which have not been completely sterilized in the canning process and in which the *Clostridium botulinum* organism develops its powerful poison.

Home-canned string beans and home-canned corn have frequently been sources of botulism. Almost nine-tenths of the poisonings observed in the United States are caused by vegetables of various sorts preserved in brine; animal products are involved in less than one-fifth. Canned goods containing a large amount of liquid appear more liable to the contamination than do relatively dry products.

"While it is possible that ingredients such as eggs, milk, or wheat may be the vehicles of infection carrying poisoning organisms into the prepared mass, their development there is possible only because of failure to destroy them by adequate heating or to prevent their development by sufficient preparation," states a government bulletin on food poisoning.

"Foods such as meat pies, scalloped fish or oysters, hash, some salads, puddings, custards and cream pie fillings are frequently the cause of illness due to the fact that in the process of preparation insufficient heating is used to destroy the bacteria or their toxins and such prepared foods offer extremely favorable conditions for the development of bacteria if inadequately heated and improperly stored after preparation."

In the case of botulism, the food itself is made poisonous by the contaminating organism. Sometimes there is present an infection which makes a poison in the body of the host after the food is eaten.

Trichinosis is often regarded as a form of poisoning caused by underdone pork. In reality it is a disease caused by a parasite contained in infected pork. If the meat is sufficiently cooked to kill the parasite, the same pork can be eaten without dangerous results.

"Ptomaine poisoning" was at one time a popular explanation for the majority of cases of food poisoning. It was thought that protein foods degenerated into a toxic substance. This theory is now dismissed as false, and infection is blamed for the majority of food poisoning.

Occasionally harmful chemical adulterants in food cause poisoning. Cases of gin paralysis have been traced to a poison present in adulterated forms of Jamaica ginger. Some cases of food poisoning have been traced to toxic substances contained in silver polish and consumed with the food.

Several epidemics of food poisoning on the Pacific Coast have been traced to a variety of mussel which becomes poisonous during the summer months. At first it was thought that the sickness incurred from eating the sea food might be caused by bacteria or by some pollution but investigation has revealed that it is due to a poison originating in the mussel itself, the actual cause of which is unknown.—*Science Service*

HIGHLY PURIFIED IRON OBTAINED FROM LIQUID COMPOUND

Highly purified iron, possessing many of the qualities of copper, is prepared in Germany by a new process described recently by DR. ING. L. SCHLECHT.

Carbon monoxide of a high degree of purity is passed over hot iron previously purified by ordinary methods. The two unite to form a liquid of relatively low boiling point, iron carbonyl. Heating this drives off the carbon and oxygen, leaving iron, with hardly a trace of impurities, in an exceedingly finely powdered form. The individual spherical particles are only 20 millionths of an inch in diameter.

Heating this powder to a temperature of 1200 degrees Centigrade—twelve times as hot as boiling water—changes it into solid iron that resembles copper in its softness, resistance to corrosion and other properties. The process is declared to be applicable on a large scale, and the product to be much more useful than ordinary iron for many purposes.

German patents on the process are held by the great manufacturing concern, the I. G. Farbenindustrie A.-G. of Ludwigshafen am Rhein.—*Science Service*

LUMBERING WASTE LESS THAN SUPPOSED

While a period of business depression focuses public attention on waste, the Office of Products of the U. S. Forest Service at Missoula, Montana, has issued charts which indicate that a larger part of Douglas fir and Western larch trees are utilized when they are cut for lumber than is commonly supposed.

When a Douglas fir is cut in Montana and northern Idaho, 63.9 per cent of the tree is converted into lumber and 13.2 per cent is otherwise utilized, the report indicates; when the larch is felled, only about 57 per cent becomes lumber, while 12 per cent is converted into other products.

The disposition of the average Douglas fir is summarized in this manner: 10 per cent of the tree is left in the forest, including breakage, stumps and tops, and usable and unusable limbs; while 90 per cent goes into saw logs. Seventy-one per cent of the saw log becomes lumber while 29 per cent is converted into slabs, sawdust, edgings, and trims. A portion of this 29 per cent of the saw log is utilized in making lathes, fuel wood, molding, and box stock, and represents 16 per cent of the log, the net log waste being 13 per cent.

As 10 per cent of the tree is left in the forest and 13 per cent of the log is wasted at the mill, the total unutilized part of the 100 per cent tree is 22 per cent.

Scientists are striving to develop new pulp and plastic by-product industries which will use a portion of the wood wasted in lumbering and logging.—*Science Service*

PELLAGRA MAY BE DUE TO LACK OF IRON IN DIET

Lack of iron in the diet rather than lack of vitamin G may be the cause of pellagra, a skin and nervous disease which is prevalent in some rural districts of the southern states, it appears from studies which DR. SIDNEY BLISS of Tulane University School of Medicine has reported to the journal, *Science*.

The diet of corn bread and molasses on which most of the poor people in the South live is lacking in iron as well as in vitamin G, Dr. Bliss pointed out. Furthermore, all the foods listed as preventive or curative of pellagra because of their

large vitamin G content, also contain large amounts of iron. Among these he mentioned beef liver, egg yolk, and yeast.

Fifty-one persons suffering from pellagra were accordingly given iron by intravenous injection. The results are encouraging, Dr. Bliss reported, although it is still too early to state whether these patients will recover entirely from the disease on iron alone.

Dr. Bliss and associates also studied the effect of iron on dogs suffering from black-tongue, considered by some authorities to be the canine counterpart of pellagra. The dogs were fed on a diet of peas, cracker meal, and cotton-seed oil. Black-tongue developed in all its severity. When iron was injected into the veins of these animals, the animals promptly recovered although no change in diet was made.

Pellagra is practically unknown in very young children, under two years of age. Moreover, as compared with adults, children, puppies, kittens, and rabbits are born with about three times the concentration of iron in the body, Dr. Bliss pointed out.

Anemia, which is a frequent accompaniment of pellagra, may be "yet another finger pointing to an iron deficiency in pellagra," Dr. Bliss suggested.—*Science Service*

White Hot Platinum Is New Light Standard. Molten platinum, precious metal, shining with heat, gives the world its best standard of light with which to compare the brightness of lamps or the stars.

At the National Bureau of Standards four physicists have produced this new light standard. Using an idea suggested by Dr. G. K. Burgess, now director of the Bureau of Standards, and his associate, the late Dr. C. W. Waidner, the platinum light standard was tested experimentally by Dr. H. T. Wensel, William F. Roeser, L. E. Barbrow, and F. R. Caldwell of the Bureau's staff. A flame of standard type burning fuel at a known rate has been used in the past as a standard but its brilliance varies with changes in atmospheric conditions.

Platinum, pure to one part in 30,000, is fused electrically in crucibles of thorium oxide.

Comparisons with its light are made when the platinum is melting or freezing. Its temperature then is about 3200 degrees Fahrenheit. Light produced under these circumstances is remarkably constant. Reproducibility is of first importance for a standard and the values of the platinum standard are repeatable to a tenth of one per cent. The precise value of the new light standard is 58.84 international foot candles per square centimeter.—*Science Service*

Electric Separation Carries Electrons through Air Space. Electrolysis, or electric separation of the elements in a chemical solution, is carried on in a new way by a process invented by Prof. Alfons Klemenc of the University of Vienna. The method promises results of great importance in research, and possibly also in industry.

In ordinary electrical separations, both positive and negative electrodes are immersed in the solution to be treated, and each takes out the atoms or atom-groups that are attracted to it. In Prof. Klemenc's process, the negative electrode is suspended above the surface of the liquid, and separated from it by an air space. When the current is turned on, a stream of electrons is given off by the electrode into the air.

The electrical phenomena that accompany this kind of electrolysis are quite different from those of ordinary electrolysis, Prof. Klemenc states. Electrolytic reduction is carried on more easily, and electrolytic oxidation proceeds much more intensely.—*Science Service*

Recent Books

A History of Chemistry. F. J. MOORE, Late Professor of Organic Chemistry, Massachusetts Institute of Technology. Revision prepared by William T Hall, Associate Professor of Analytical Chemistry, Massachusetts Institute of Technology. Second edition. McGraw-Hill Book Company, Inc., New York and London, 1931. xxiii + 324 pp. 78 plates. 14 × 20 cm. $3.00.

This volume was constructed from a series of lectures which dealt with the fundamental ideas of the science; their origin, their philosophical basis, the critical periods in their development, and the personalities of the great men whose efforts have contributed to that development. The person addressed is the more mature student of chemistry, though few portions of the book will present serious difficulties to the general reader. The aim has been to emphasize only those facts and influences which have contributed to make the science what it is today; the claim of a topic for consideration has been not its practical but its historical importance. It has been asked, not whether the work was itself of value, but did it contribute a new fundamental idea. Little attention has been paid to questions of priority. The general plan of the book remains unchanged in this second edition; the content has increased about five per cent by the inclusion of new material. Recently discovered data have in a few cases necessitated the restatement of facts. It is pointed out that alchemistic doctrines prevailed in China as early as they appeared in Egypt and that Basilius Valentinus probably never existed (his reputed likeness is nevertheless reproduced). Brief biographical sketches of a number of brilliant chemists who died during the last twelve years are given. An additional chapter is devoted to Americans who did much to develop chemistry in this country, no mention being made, however, of a number of eminent scientists who are still alive. A portrait of the author and an account of his life and his career as a scientist and teacher precede the text proper.

The author has done his work well, within the limits he has set for himself. The text has stood the test of classroom use and with the coöperation of a widely read instructor it can serve as an excellent framework on which to build an introductory course. It is frankly a textbook and suffers from the evils which are the necessary accompaniments of its didactic objectives. Biographical paragraphs are informing, but are usually uninteresting and never make for smooth reading.

The title of the picture by Chartran facing p. 66 is not correct, an error that occurs in several other texts. The painting hangs in the Sorbonne, but Lavoisier had no connection with this school and certainly did no work there. The scene is usually labeled "Lavoisier converting Berthollet to the antiphlogistic doctrine." Rouelle lectured at the Jardin du Roi (des Plantes) and not at the Collège Mazarin (p. 52). Lavoisier was condemned on a trumped-up charge of treason, the watered tobacco actually playing a minor rôle in the long list of accusations brought against him and his fellow Fermiers Généraux. The reviewer cannot agree with the statement (p. 232) that Baeyer was a practical empirical chemist rather than a theoretical dreamer. The biography of Nef (p. 307) was written by L. W. not L. F. Jones. Le Chatelier assuredly deserves mention for something more than his translation of Gibbs' paper on heterogeneous equilibrium.

A little more care might have been used with regard to the references suggested for further reading. None of the standard English histories of chemistry are mentioned, the numerous recent books and particularly the articles in the periodicals

are largely ignored; definite citations to the literature could well have been incorporated in the body of the text. In some cases the original German works are recommended although English translations are now available, a rather surprising condition if viewed in the light of the statement (p. 307) that "Nef's writings are hard to read, partly because they are published for the most part in German." This fault can easily be remedied in the next edition, for so useful a book deserves to be brought up to date periodically.

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Makers of Chemistry. ERIC JOHN HOLMYARD. First edition. Oxford University Press, 1931. 314 pp. 58 illustrations. 12 × 18 cm. $2.50.

Eric John Holmyard (M.A., Cambridge) is an investigator in pure chemistry, a teacher of experience, and author of various texts in chemistry. His interest in the pedagogical side is shown by his book, "The Teaching of Science." He has become especially well known on account of his work in the history of chemistry where his investigations in the Arabic sources of chemistry and in the Jabir problem have been of very great value. Mr. Holmyard has an advantage, as a historian of chemistry, in his background of scholarship and experience, wherein he differs from some of the late popular writers in this special field.

For the general student the most difficult part of the history of chemistry is the early period, and in this respect this book is a very decided contribution. As an expert chemist, the author has evaluated the findings of archaeology concerning the technical arts of the ancient world, whose development played such an important rôle in its political history. It is a matter of interest to the student of today to realize that 3000 years B.C. the Egyptian Court had a monopoly of the mining and metallurgy of copper, while the gold mines of Nubia, where the metal occurred, evidently in quartz veins, were worked by slave and prison labor with a ruthless disregard for health or life.

The author deals at some length with the achievements of the Muslim chemists and it gives a human note to our science when we realize that Jabir, one of the great names in chemistry, was an attendant at the court of that Harun al-Rashid at Bagdad of whom we used to read in the "Thousand and One Nights." This relationship between chemistry and the Arabian court may account for some of the stories in the "Thousand and One Nights" which involve the ideas of alchemy. What the western scientists really owe to Muslim sources the author well illustrates by the following observation taken from a Spanish book written a thousand years before the classic experiments of Priestley and Lavoisier: "I took natural quivering mercury, free from impurity, and placed it in a glass vessel shaped like an egg. This I put inside another vessel like a cooking pot and set the whole apparatus over an extremely gentle fire. The outer pot was then in such a degree of heat that I could bear my hand upon it. I heated the apparatus day and night for forty days, after which I opened it. I found that the mercury (the original weight of which was $^1/_4$ lb.) had been completely converted into a red powder, soft to the touch, the weight remaining as it was originally." Mr. Holymard remarks: "That no gain in weight was observed is not surprising, as some of the mercury would probably have been lost by volatilization, while the increase in weight of mercury on oxidation is only about 8 per cent. The fact, however, that the author attempted to carry out the experiment quantitatively is in itself important, as indicating that he paid attention to a fundamental chemical rule not universally observed until centuries later."

Mr. Holmyard gives an account of the contributions (with good perspective) of Roger Bacon, Paracelsus, Van Helmont, Lémery (who was possibly the first writer

of a textbook that brought him a fortune in the way of royalties), John Mayow, who like Priestley failed to interpret his experiments on "vital air" correctly, and other "Makers of Chemistry." He pays tribute to G. F. Rouelle (1703–70), who is apt to be sparsely treated in the ordinary history, and states that he "is one of the greatest teachers of chemistry that France or the world has produced . . . . the first to clearly define the nature of a salt and to give a systematic classification to this important class of compounds."

The phlogiston theory and the cause which led to Lavoisier's great pronouncement are well set forth. The last fifty pages of the book are devoted to the classification of the elements, the rise of organic and of physical chemistry, and to the structure of the atom.

The book is well printed and its numerous and well-chosen illustrations greatly enhance its interest. In short, the volume is a most readable and accurate account, especially of the period before 1800, and one which the reviewer would gladly see in the library of every student of chemistry.

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General Chemistry, Theoretical and Descriptive. THOMAS P. MCCUTCHEON, HARRY SELTZ, AND J. C. WARNER, Second edition, D. Van Nostrand Company, New York City, 1931. xvi + 533 pp. 43 figs. 11 portraits. 21.5 × 14 cm. $3.50.

In the second edition of this text the authors have retained the division of the subject matter into theoretical and descriptive sections. The former has been enlarged, particularly in the treatment of the relations between atomic structure and the periodic system, and in the interpretation of the theory of solutions in terms of the electron theory. There is as much physical chemistry in the 221 pages of Part I as is to be found in any first-year text. The frequent use of mathematical formulas should early accustom the student to think in these terms.

There is nothing in the descriptive half of the text to offset the grimness of Part I. The authors have held to their intention not to popularize the subject; they state in the preface that "no historical material has been used, and references to industrial processes have been made as concise as possible." The only human touch in the book is to be found in the eleven portraits reproduced from the Edgar F. Smith Memorial Collection in the History of Chemistry.

The text is well adapted to the needs of the students who expect to enter science as a profession, but the reviewer wonders just how "practical and useful" it has proved to the students pursuing the liberal arts course. The judgment which these students have passed upon similar required courses in chemistry during the last decade or two could hardly be expressed in such terms. Perhaps the syllabus of lectures, appended to the preface, provides the means whereby a gifted lecturer can give material of more interest and value to this large group of students.

JOHN R. SAMPEY
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A Shorter Course in Organic Chemistry. J. C. COLBERT, Assistant Professor of Chemistry, University of Oklahoma at Norman, Oklahoma. (The Century Chemistry Series, James Kendall, *Editor.*) The Century Company, New York City, 1931. xviii + 352 pp., diag. (Part fold.) 15 × 23.5 cm. $3.60.

Although entitled "A Shorter Course in Organic Chemistry," Colbert's text is by no means superficial or fragmentary in its treatment of the beginning organic chemistry. It is in fact generously full in its treatment of the fundamental concepts and the classes of compounds of primary importance.

One of the chief merits of the text is that it is very obviously written for the beginning student, with the limitations of such a student in mind. Large clear structural formulas are used throughout and the author is not afraid to explain

complex phenomena in relatively simple words. Nor does he hesitate to talk directly with the student, giving in a conversational tone, definite and excellent suggestions for both study and review.

The text includes unusually splendid charts which show in a graphic manner the relationships existing between numbers of compounds of any given series. These charts are well presented and illustrate a fine point in teaching. They add greatly to the value of the text. The table of contents is unusually full, being in effect almost an outline of the text, chapter by chapter. Problems, review questions, and suggestions are to be found at the end of each chapter. Approximately two-thirds of the book is devoted to the development of aliphatic chemistry and the remainder to a somewhat briefer treatment of the aromatic and heterocyclic compounds. At the end of the aliphatic chapter is a review chapter and very good chart showing the main relationships of the several classes of compounds of this section. These well-ordered and well-selected charts constitute a most admirable point in this new text.

A small thing but indicative of the author's attempt to make the text usable for the beginner is that where a substance is listed in the index in more than one place, the reference is given each time rather than the more usual custom of referring the student from the least to the more common name.

This text is well written and well published and should prove a worthwhile addition to the too few good introductory texts in this field. It is notable: (1), in its effort to present organic chemistry as a unified whole; (2), in its informal and forceful style; (3), in its attention to and constant use of review, and (4), in its successful presentation of the subject in such a manner that the beginning student can really get the subject.

O. R. QUAYLE
J. SAMUEL GUY

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The Colorimetric and Potentiometric Determination of pH. I. M. KOLTHOFF, Ph.D., Professor of Analytical Chemistry in the University of Minnesota. John Wiley and Sons, Inc., New York City, 1931. xi + 167 pp. 35 figs. 15 × 23 cm. $2.25.

This book is designed to serve as a text and partial laboratory manual for a six-credit, two-quarter course in the theory and methods for the colorimetric and electrometric determination of acidity. Although based on the well-known works of Kolthoff and Furman on Indicators and Potentiometric Titrations, it is in no sense merely an abbreviation of them, but is a complete, although not comprehensive, work in itself.

It is divided into three parts—colorimetric methods, potentiometric methods, and conductimetric methods. Each section begins with a first-class discussion of the theory involved and is followed by a rather detailed description of the various methods. These descriptions are sufficiently detailed for any one with a reasonable background in physical chemical methods to follow with ease. The errors and pitfalls of the various methods are carefully called to the attention of the reader. Each chapter is closed with a series of excellent problems based on the preceding material. The book closes with an outline for a practical course involving the methods previously described. Numerous tables of data furnish most of the material needed in connection with the experiments and problems. Like the other Kolthoff books, it is well supplied with references.

Dr. Kolthoff does not claim that this book is in any sense comprehensive, yet it is the reviewer's opinion that one thoroughly familiar with its contents should have a very good grasp of this most interesting and important subject. The book may be recommended highly to all teachers of physical chemistry who offer any work in their courses along these lines, even though they may not be in a

position to give a complete course on them.

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The Nature of a Gas. LEONARD B. LOEB, University of California. John Wiley and Sons, Inc., New York City, 1931. x + 153 pp. 11 figs. 14.7 × 22.7 cm. $2.50.

This text is Monograph No. 1 published under the auspices of the Committee on Electrical Insulation of the Division of Engineering and Industrial Research, National Research Council.

The book is divided into three parts: Introduction, The Kinetic Picture of a Gas, and Ionization Phenomena. The first deals with the electrical structure of atoms and molecules. Starting with the fundamental properties of the electron the author presents in logical sequence the necessary factors that lead to the generally accepted present-day ideas of atomic nuclei, the extranuclear structure of the atom, and molecular structure.

The second chapter explains the behavior of atoms and molecules in gases under normal conditions from the point of view of kinetics. In it are discussed Avogadro's Number, Joule's Law, Mean Free Path, Molecular Velocities, and the Law of Equipartition of Energy, concluding with a summary that provides a qualitative picture of a gas.

The third part is concerned with atoms and molecules disturbed from their normal electrical states. In this portion are discussed "the conditions causing such disturbances, the laws governing them, and the nature and extent of the disturbances produced." The author treats of the various general phenomena in excitation and ionization, together with special reference to ionization in gases.

In the appendix are tables of molecular constants, such as molecular radii, molecular velocities, mean free paths, a table of useful constants and conversion factors, and a rather comprehensive bibliography of texts and papers. There is included also an index of names and one of subjects.

The book is well written, clear, and logical. The author has succeeded in presenting material in so-called Modern Physics in a manner that is interesting and understandable for those who are interested simply in science in general—readers who are intimidated by the usual complicated language and mathematical symbols of the specialist in this field. While written from the viewpoint of a physicist this book should be useful to the stu' .t of chemistry, furnishing him with concise, intelligible information on the work accomplished to date in a field in which both are so vitally concerned. It should be especially valuable to engineers "who are concerned with the problems of the behavior of dielectrics as insulation," in that it provides basic information on the nature and electrical properties of a gas.

CHAS. G. EICHLIN
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The First Course in Quantitative Analysis. FLOYD HAMILTON FISH, M.S., Ch.E. Professor of Analytical Chemistry, the Virginia Polytechnic Institute. P. Blakiston's Son & Co., Inc., Philadelphia, 1931. x + 120 pp. 3 figs. 19 × 13 cm. $1.25 net.

Part I of this little book is arranged for engineering and applied science students and Part II for agricultural and home economics students; the difference being in the nature of the laboratory exercises. In Part I these consist of the preparation and standardization of the commoner volumetric solutions and their use in the titration of various mixtures of hydroxide, bicarbonate, and carbonate of sodium, and in the determination of iron, copper, and chlorine. The gravimetric exercises are the determination of iron and sulfate in a salt, and moisture loss on ignition, SiO_2, R_2O_3, CaO, and MgO in limestone. Part II uses some of the exercises of Part I but contains mostly work in feed and fertilizer analysis.

The book is characterized by original points of view and by whatever vigor of expression comes with writing as one talks in the laboratory. Such writing, however, breeds carelessness of expression. For example, the following occurs on page 9. "A liter is the volume or space occupied by 1000 cubic centimeters of water. One cubic centimeter of water weighs one gram; 36.46 grams of pure HCl gas will, when diluted to 1 liter, make a liter of normal hydrochloric acid; . . . ." It is perhaps splitting hairs to say that a liter is not 1000 cubic centimeters, whether of water or something else. Nevertheless, the fact that it is not is recognized by the growing use of the term milliliter. The unqualified statement that a cubic centimeter of water weighs one gram is grossly inaccurate, and the expression, 36.46 grams of pure HCl gas diluted to a liter, is so far removed from the real situation handled in preparing a normal solution that no proper mental picture can be expected in the mind of the student.

The reviewer believes that the English language is the most important instrument at the disposal of an American professor of analytical chemistry, and that it should be used as an instrument of precision.

The original points of view are mostly pedagogical. Some of them are good and some of them are, at best, matters of opinion. Here is one on which opinions might vary. "The 'chemical factor' habit for the beginner, while very useful, is indeed a great hindrance to rapid readjustment in thought." A footnote is then appended (page 1) as follows. "The term, chemical factor, is not used in this course." It would now be unfair not to give at least a hint of the author's argument against the chemical factor habit. This quotation (page 2) will serve. "It would seem absurd if one had to calculate a 'factor' before he could solve the following problem:

"If 5 apples cost 25 cents, what will 75 apples cost?"

An outstanding good point in the book is the treatment of the elementary problems in gravimetric and volumetric analysis. Students who are having difficulty in solving such problems and teachers who are having difficulty in teaching them should purchase a copy of Professor Fish's little book. It contains many typical problems with accompanying solutions clearly set down.

C. W. FOULK

THE OHIO STATE UNIVERSITY
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Dry-Cleaning and Redyeing Handbook, Including Laboratory Practice, Formulas, Tests, and Tables. C. C. HUBBARD, for many years Director of Research and Education for the National Association of Dyers and Cleaners of the United States and Canada and the National Association Institute of Dyeing and Cleaning, Inc. Associate editors: Edwin R. Donaldson, graduate of Bradford-Durfee Textile School, and Mable F. Falling, for four years Assistant Research Associate, U. S. Bureau of Standards. First edition. Rock Crest, Silver Spring, Maryland, 1929. ix + 252 pp. 10 × 16 cm. $5.00.

This handbook offers in practical style quick reference information about the general principles and methods of drycleaning and redyeing garments and other textile materials.

Marginal numbers divide the book into ten sections: (1) Dry-Cleaning Practice; (2) Stain Removal; (3) Wet-Cleaning Practice; (4) Bleaching and Stripping; (5) Dyestuff Application; (6) Finishes; (7) Tests; (8) Tables; (9) Definitions; and (10) Useful Information. The first six of these sections describe in sequence the steps of the dry-cleaning and redyeing processes and give specific directions for the various procedures and a critical discussion of the difficulties involved. This is by far the best part of the book. Section 7, Tests, consists of methods for the preparation and testing of laboratory reagents and an uncritical compilation of methods for the qualitative and quantitative analysis of textiles. Section 8,

Tables, includes conversion tables for weights, measures, thermometric scales, and density scales, specific gravity tables for aqueous solutions of ammonia, sodium hydroxide, sodium carbonate, acetic, formic, hydrochloric, and sulfuric acids, sodium hypochlorite, sodium hydrogen sulfite, and ethanol, recipes for antifreeze solutions, and a table of the effect of water hardness on soap. Section 9, Definitions, is not good; the author has not been successful in defining scientific terms for the practical workman, although his technological terminology has an effective tang. Section 10, Useful Information, is a miscellany of a list of laboratory equipment and supplies, first-aid instructions, methods for the preservation of chemicals, data on the use of pulleys, belts, and motors, a discussion of the effect of dry-cleaning on fur, leather, and the rayons, some mensuration formulas, physical units, quantities, and formulas, and a bibliography of dry-cleaning. A list of typographical errors is pasted inside the front cover of the handbook, which has a detailed table of contents and a very good index.

This handbook, a condensation of previous efforts of the author's practical experience, is to be recommended to any one not familiar with the dry-cleaning industry who wishes to obtain an outline of the maintenance of textiles by dry-cleaning as well as to the practical workman for whom it was prepared and to the student of textiles who wishes a reference work on dry-cleaning technology and a recipe book for methods of stain removal and for the redyeing and the refinishing of used textiles.

RACHEL EDGAR

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MISCELLANEOUS PUBLICATIONS

Useful Information about Lead. Published by Lead Industries Association, 420 Lexington Ave., New York. Cloth bound. 104 pp. 13.5 × 20.0 cm. $0.50 postpaid.

This book tells concisely the story of lead and its principal uses and should be of interest and practical value to every teacher as well as to every user of lead and the multitudinous products derived from it. Short chapters are devoted to the major industries consuming lead and the part lead plays in them, as well as the history, mining, smelting, and refining of the metal, best indicated by the following chapter titles: Mainly Historical, From Mine to Finished Metal, Grades of Virgin Lead, Physical Properties of Lead, Lead Alloys, Chemical Corrosion Resistance of Lead, Lead Compounds, Lead Paints, Metal Protective Lead Paints, Lead Storage Batteries, Lead-Covered Cable, Lead in Plumbing, Ammunition, Architectural and Ornamental Qualities, Some Miscellaneous Uses, Industries Using Lead. The table of properties of lead is probably the most complete and up to date ever published, including mechanical, thermal, electrical, optical, and other constants. The chapter on lead compounds describes the manufacture and use of the more important varieties and has appended a table of many others, their characteristics, manufacture, and uses. Many corrosive chemicals handled in lead equipment are listed and typical formulas of important classes of alloys are given.

The High-School Science Library for 1930–31. HANOR A. WEBB, George Peabody College for Teachers, Nashville, Tennessee. Reprinted from the *Peabody Journal of Education*, Volume 9, No. 1, July, 1931. 12 pp. 17 × 24 cm. $0.10.

Obtainable from the author.

Government Publications

The following recent publications of the Office of Education, Department of the Interior, may be obtained from the Superintendent of Documents, Washington, D. C., at the prices indicated.

Record of Current Educational Publications (Indexed), 1931, No. 9, $0.15.

Educational Directory, Bulletin, 1931, No. 1, $0.35.

Accredited Higher Institutions, 1930, No. 19, $0.20.

Accredited Secondary Institutions, 1930, No. 24, $0.25.

Special Schools and Classes, 1930, No. 7, $0.10.

Statistics of Public, Society, and School Libraries, 1930, No. 37, $0.50.

Land Grant Colleges and Universities, 1930, No. 28, $0.15.

Statistics of Private High Schools and Academies, 1929, No. 19, $0.10.

Research Bureaus in City School Systems, Leaflet No. 2, $0.50.

Private and Endowed Schools Offering Trade and Industrial Courses, 1928, No. 18, $0.10.

Industrial Education Section of the Buffalo Public School Survey, Pamphlet No. 17, $0.10.

Current Practices in the Construction of State Courses of Study, Bulletin, 1931, No. 4, $0.15.

College and University Education 1928–30, Biennial Survey Chapter 8, Bulletin, 1931, No. 20, $0.10.

Engineering Education, Biennial Survey Chapter 16, Bulletin, 1931, No. 20, $0.05.

New Check on Earth's Age. New measurements on a very old mineral have given the possibility of a new accurate determination of the time since the molten earth cooled sufficiently to form a solid crust. This new glimpse into the past of the earth comes as a result of the work of Dr. A. von Grosse and Dr. J. D. Kurbatow working at the Institute of Technology at Berlin.

That the earth is at least 1800 million years old is one of the conclusions recently reached as a result of studies in physics and geology by the Committee of the National Research Council. A revision of previous calculations may be necessary, however, since the recent work. Physicists have grown accustomed to changing their estimates on this problem from time to time. During the last century, before the discovery of the radioactive atoms like radium, the noted British scientist, Lord Kelvin, was quite sure that the sun even could not be older than 50 million years; and of course the earth had to be younger than the sun.

The new research in Berlin indicates that the ratio of actinium to radium is four per cent in the "Wilberforce uranite" examined. This fact gives a new check-up on the reliability of the most accurate clocks used by physicists in solving this problem. Those clocks are provided by the unchanging disintegration of heavy radioactive atoms into lighter atoms.

As this process has been going on for millions of years at the same rate as now, it is possible, by measuring the amount of lighter atoms formed, to know how long the break-up has been going on. These lighter atoms are very similar in nature to lead, and cannot be distinguished from it by ordinary chemical means. Separate clocks are given us by three different chains of elements which start from uranium, thorium, and the yet-unknown parent of proto-actinium. The end of the uranium chain is radium "G," of the actinium chain is actinium "D." By measuring the amounts of lead, uranium, and thorium and the relative amounts of radium G and actinium D two independent checks on the age of the earth can be obtained from the radium clock.

The new figure given for the actinium–radium ratio is different from that accepted by the National Research Council Committee by three per cent.

At present the greatest possible age for our planet is believed to be 3000 million years.—*Science Service*